# Forest Research Review

## 1981-82

## COVER PHOTOGRAPH

### Yield Predictions by Computer Simulation

The computer depicts the aerial view of several trees in a simulated forest. These crowns will expand and compete for growing space within the 3-dimensional environment of the computer in response to the productivity of the land, spatial distribution of the trees, fertilization, thinning and other forces which affect the development of forests. Wood is added to the stem of each tree annually, in relation to the size of the crown, and accumulated to provide estimates of the quantity and quality of wood produced by our second-growth forests such as the one in the background. This computerized yield prediction system generated managed stand yield tables for coastal Douglas fir (EP 927) and interior lodgepole pine (EP 850) in 1982.

photo by J. Thomson
design by K. Seabrook

# Forest Research Review

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## DIRECTOR'S REPORT

Research Program expenditures in 1981/82 amounted to 9.2 million dollars which included 5.7 million for headquarters research, 2.6 million for regional research and 0.9 million for Section 88 (licensee) research. Expenditures by program are as follows:

| RESEARCH PROGRAM SECTIONS | |
|---|---|
| . Ecology and Earth Sciences* | $3,479,257 |
| . Tree Improvement | 827,928 |
| . Silviculture | 1,372,638 |
| . Tree Physiology | 407,781 |
| . Biometrics | 350,996 |
| . Support Services | 1,593,642 |
| . Program Administration | 268,538 |
| | $8,300,780 |
| . Section 88 (licensee) research | 868,000 |
| TOTAL | $9,168,780 |

*includes $100,000 received from Canada Department of Fisheries and Oceans, and Ministry of Environment in conjunction with the cooperative Fish/Forestry Interaction Program on the Queen Charlotte Islands.

During 1981/82, considerable emphasis was placed on stengthening headquarters research capability and support services in key areas to meet the requirements of branches and regions. Progress can now be made in addressing such critical issues as managed stand yield tables, plantation growth and survival on severe sites and the control of competing vegetation. Serious efforts are also being made to increase research 'outputs' so that the Research Program makes a substantial contribution to solving problems associated with implementing forest and range management programs. This involves the publication of reports, field handbooks and guides, as well as actively providing technical consultation and research extension services to field practitioners.

Growth and yield specialists were active in processing data from 1 500 permanent sample plots with the assistance of six contract researchers and support staff in a continuing program to produce managed stand yield tables for important commercial species. Growth and yield information from British Columbia is strengthened by plot data from Alberta, Washington, Oregon, Idaho, New Zealand, Great Britain, Finland, Sweden and France. The preparation of yield tables (first approximation) for coastal Douglas fir and interior lodgepole pine is near completion. These tables will incorporate plantation establishment, density and juvenile spacing as management variables.

Two pilot forest fertilization installations were established at Lac Le Jeune to mark the start of a new five year program to improve the growth and yield information data base for interior regions. On the coast, work continued on editing and processing Forest Productivity plot remeasurement data with the objective of publishing six-year results by the end of 1982.

A highlight of the ecology and earth sciences program was the publication of the Taxonomic Classification of Humus Forms in Ecosystems of British Columbia by K. Klinka, R.N. Green, R.L. Trowbridge and L.E. Lowe. This report will facilitate consistent humus type identification, improve silvicultural interpretations and stimulate further research into humus forms. The classification is being considered for incorporation into the Canadian System of Soil Classification.

Additional studies were initiated in several integrated resource management research projects. These include increasing our understanding of the relationship between forestry and wildlife habitat in several parts of the province, as well as new studies on fish/forestry interactions on the Queen Charlotte Islands.

Research in tree physiology benefited by the establishment of three additional permanent positions which will address research projects formerly conducted on contract or by auxiliary staff. This action came about as a result of a continued need for improving the performance of nursery stock destined for planting on difficult sites such as high moisture stress sites and highly productive sites prone to brush invasion. A seed physiology laboratory was established at North Road to consolidate research formerly conducted at three locations.

The Research Branch was under increased pressure to expand tree improvement research in some species already under study, and to initiate comprehensive programs in additional tree species.

In response to needs identified by the recently-formed tree improvement cooperatives, a major initiative of the tree improvement section during 1981-82 was the rigorous review of all breeding strategies and programs. This was carried out by Ministry geneticists in collaboration with academic and private sector expertise.

The Kalamalka Research Station and Seed Orchard was officially opened by the Honourable Tom Waterland, Minister of Forests, on September 25, 1981. The $1.2 million facility plus adjacent lands for tree breeding and seed orchards consolidates both the research and operational components of the tree improvement program in the southern interior. Excellent research facilities are provided for tree breeding, silviculture and tree physiology research programs. The operational staff responsible for seed orchard management is also housed in the building.

The staff complement in biometrics and data processing services now includes nine biometricians, one programmer analyst and a data control clerk. Progress was made in providing researchers with convenient routines for analyzing their own data. The programmer analyst visited all regional headquarters and taught procedures for using newly installed computer terminals. This was followed by training in each region on data analysis techniques and procedures. Development of this expertise among the researchers will help reduce delays in data analysis and permit biometrics staff at headquarters to spend more time on other demands for services.

Information and operational implementation continued to receive considerable attention. Four issues of Forest Report were published and its circulation increased to near 8 000. Several regions published interim results and supportive guides associated with their ecosystem classification programs. Five books were published in the Land Management Handbook series and six in the Land Management Report series. Two of the Land Management Reports were the result of cooperative projects with other Provincial Government ministries.

Training programs continued in all regions, and over one thousand operational staff members attended a variety of courses in ecosystem classification, fertilization and spacing, site rehabilitation, as well as in various aspects of tree improvement. The research section of the Prince Rupert Forest Region broke new ground by recruiting a training officer and a research extension forester to actively pursue the operational implementation of research results.

## TREE PHYSIOLOGY

Research conducted by the Tree Physiology Section is of an applied nature. The studies are directed ultimately to forest regeneration through solution of technical and biological limitations encountered in all phases of the life cycles of British Columbia conifers.

There were 40 active experimental projects (E.P.'s) in 1981/82, comprised of two new numbers and many new sub-E.P.'s. Due to their nature several are reported under the Forest Regeneration section of this review.

The section also operates an analytical laboratory satisfying major Ministry operational and research needs for inorganic analyses of soils, plants, and water.

### SEXUAL REPRODUCTION

Staining marker studies with Douglas fir pollen and timed application studies on lodgepole pine showed improved seed yield and genetic gain can be achieved in seed orchards of both species, provided supplemental pollination is timed within the first few days of female cone receptivity.

One of nature's best kept secrets, the control of cone production for assured seed supply and tree improvement acceleration, appears to be yielding through diverse attacks. These include developmental anatomy studies explaining sequences and patterns at the cellular level capable of being modified through hormonal and cultural treatment combinations. Information is being extended on responses from specific gibberellins and formulation research promises higher efficiency cuticular penetration and ultra low volume spray techniques. Container seed orchard research is clarifying the role and utilization of environmental factors of flowering. Timing, duration and intensity of treatments are being refined. Studies have been initiated in crown management of Douglas fir and western hemlock seed orchards.

#### CONE INITIATION AND SEED DEVELOPMENT IN MOUNTAIN HEMLOCK (E.P. 738) J.N. OWENS

Putative pollen-cone and seed-cone buds were collected from several locations over several years. It was not until 1981 however, that the trees from which collections were made initiated reproductive buds.

Specimens were collected from several trees near Sooke, B.C. throughout the 1981 growing season and have been sectioned. The anatomical development of vegetative and cone buds is now being studied for completion in the summer of 1982.

## SEXUAL REPRODUCTION IN PINUS CONTORTA (E.P. 830) J.N. OWENS

This project has been completed and a description of ovule, embryo and seed development submitted for publication.

Postdormancy development of the ovule, fertilization and embryo and seed development of lodgepole pine are described. Emphasis is given to the phenology of reproduction within its natural range and outside its natural range, compared to the phenology of shore pine growing within its natural range.

The female gametophyte of lodgepole pine overwinters at the free nuclear stage, resumes development in early April and is mature by mid-June. Fertilization occurs in mid-June and the embryo and seed are mature by early August. Lodgepole and shore pines growing in the coastal region complete each stage of development about one month earlier than lodgepole pine grown in the interior of British Columbia. Stages of the reproductive cycle are described as they effect potential seed.

## CONE INITIATION AND SEXUAL REPRODUCTION IN ABIES LASIOCARPA (E.P. 832.01) J.N. OWENS

Cone initiation in subalpine fir occurs infrequently on most trees. Consequently, collections to determine the time and method of cone initiation were made over several years near Prince George. In 1980 and 1981 some cone initiation occurred and the study was based primarily on these collections.

Cell divisions began in vegetative buds early in April followed by bud scale initiation over 10 weeks. Buds were initiated in the axils of some leaf primordia about the time of vegetative bud burst, one month after vegetative bud dormancy ended. All buds completed bud scale initiation by the end of June. This coincided with the end of the rapid phase of lateral shoot elongation. This was followed by a 2 week period of bud differentiation. Leaf and bract initiation began by mid-July and continued until mid-October when these buds became dormant. Microsporophyll initiation began earlier, was nearly completed by the end of July and pollen cone buds became dormant in mid-September.

The number of cone buds was determined by the proportion of axillary bud primordia that fully developed and the pathway along which they developed. Potential seed-cone buds may become latent but were not observed to differentiate into vegetative buds. The position of the axillary bud on the shoot, and of the shoot in the tree strongly influences axillary bud development in Abies.

## CONE INITIATION AND SEXUAL REPRODUCTION IN ABIES GRANDIS (E.P. 832.02)

J.N. OWENS

Specimens were collected in 1980 and 1981 to determine the time and method of cone initiation, the normal growth cycle of vegetative buds, and to describe sexual reproduction of the species. Little cone initiation occurred in 1980 but sampling results improved in 1981. Specimens of putative reproductive buds have been examined and the time of cone-bud differentiation occurs early in July. Details of differentiation are now being studied.

Sexual reproduction has been described in detail and a manuscript accepted for publication. Pollen-cone buds broke dormancy in the third week of February and meiosis occurred by the second week of March. Pollen grains matured and were shed at the 5-celled stage in the third week of April.

Ovulate-cone buds broke dormancy at the end of January. Megaspore mother cells differentiated by the end of February and the integument initiated soon afterwards. By the third week of April the integument had developed a stigmatic micropylar funnel which received the pollen. The latter land with their body (the heavier proximal pole) touching the surface of the funnel. Numerous microdroplets were observed on the surface of the funnel, which may thus be sticky. During the post-pollination stages the funnel became infolded enclosing the pollen grains, and the nucellus elongated. Pollen germination, pollen tube growth through the nucellus and fertilization took only 3-4 days, and occurred in the third week of June. Differentiation of the root apical meristem and the cotyledons in the young embryo occurred in the first week of July, and the embryo matured in the third week of August.

## CONE INITIATION AND SEXUAL REPRODUCTION OF PICEA ENGELMANNII (E.P. 900)

J.N. OWENS

A report on sexual reproduction was published in 1981 and the study of the time and method of cone initiation was completed in 1982. The microanatomical development of vegetative and reproductive buds in Engelmann spruce is described. Vegetative buds of Engelmann spruce from the Prince George Forest Region were collected and studied. Growth, as determined from leaf primordia mitoses, resumed in mid-April. Mitotic activity in the apex was two weeks later. Bud-scale initiation in terminal buds and shoot elongation began the end of May. Bud-scale initiation of axillary buds began two weeks later. Bud-burst occurred in late June and both shoot elongation and bud-scale initiation were complete by late July. In early August, terminal vegetative buds became anatomically differentiated by the initiation of leaves. Axillary bud leaf initiation began one week later. In terminal and axillary vegetative buds, leaf initiation was completed by late September and buds ceased growth by mid-October.

Pollen cones initiated microsporophylls after bud-scale initiation. Microsporangial enlargement began in mid-September and ceased by mid-October. Pollen mother cells did not undergo meiosis before growth cessation.

Seed cones initiated bracts directly after bud-scale initiation. Groups of cells began to develop in mid-August into ovuliferous scales. Ovules formed one central megaspore mother cell which enlarged and overwintered in a pre-meiotic stage.

### THE REPRODUCTIVE CYCLES OF INTERIOR SPRUCE (*PICEA GLAUCA* AND *P. ENGELMANNII*) (E.P. 941.03) J.N. OWENS.

A text for an illustrated booklet has been prepared summarizing the entire reproductive cycles for white spruce and Engelmann spruce. The booklet is intended to present, in a less technical manner, the taxonomy, distribution, vegetative growth cycle, cone initiation and development, and the reproductive cycles of each species. The reproductive potential and problems associated with seed production are discussed.

### DEVELOPMENTAL SEQUENCES AND METABOLIC CHANGES ASSOCIATED WITH CONE ENHANCEMENT IN DOUGLAS FIR (E.P. 799.02) J.E. WEBBER AND S.D. ROSS

Cultural practices, such as root pruning and gibberellin ($GA_{4/7}$) treatments effectively enhance cone production in Douglas fir. This study seeks to define the exact timing for treatments through their effects on developmental anatomy and/or metabolic sequences in the buds and expanding shoots of Douglas fir seedlings. E.P. 799.02 is a cooperative study between the Research Branch, Ministry of Forests, Dr. J.N. Owens (University of Victoria), and Dr. R.P. Pharis (University of Calgary).

The field phase of the project using 12-year old seedlings at the Saanich Seed Orchard involved tree selection, treatments, tree sampling and monitoring both growth and coning responses. The laboratory aspect involves a detailed description of anatomical changes occurring in the bud mainstem; an assessment of hormonal changes; and variation in amino acids and carbohydrates attributed to the two treatments and combinations. Results from field aspects are reported here.

A 2x2 factorial design was used with $GA_{4/7}$ and root pruning as the main treatments. Previous results with Douglas fir showed that trees that had previously flowered had a significantly greater response to Gibberellin treatments (Forest Research Review 1977/78:9). Thus, trees were separated according to their past history of flowering. Trees were box root pruned in April 1982, about 4 weeks before vegetative bud flush, using a vibratory plow offset approximately 50 cm from the tree stem and penetrating to approximately 45 cm deep. A 50 ppm concentration of aqueous $GA_{4/7}$ containing less than 1% ethanol, was applied using the intra-vascular technique. Treatment began at the time of average vegetative bud flush and extended over a 6 week period. Rapid initial solution uptake declined to zero over a 2 week period. Hence, new holes were drilled at 2 week intervals.

Table 1 summarizes the coning response for the four treatments. As expected, a synergistic effect of root pruning and $GA_{4/7}$ combination treatment produced the largest response. Root pruning alone was more effective than $GA_{4/7}$ alone though both produced significant increases over the control in the case of trees with a previous history of flowering. On these trees, treatment response was about threefold greater than on trees that had not previously flowered.

Root pruning reduced shoot growth to about one half that of the controls (Table 2). Interestingly, $GA_{4/7}$ treatment effectively enhanced growth only if the trees had no previous history of flowering. There was also a $GA_{4/7}$ enhancement of growth for root pruned trees, again greater for trees that had not previously flowered.

The importance of this growth response may be more meaningful when analysis of endogenous gibberellins is complete, hopefully contributing to an understanding of the mechanism of regulation of flowering in Douglas fir.

Table 1. Effect of Root Pruning and Gibberellin ($GA_{4/7}$) Treatments on Flowering in Douglas Fir.*

| Treatment | Number of Seed Cone Buds Per Shoot | |
|---|---|---|
| | Trees With Previous Cone Production | Trees With No Previous Cone Production |
| Control | 0.02 | 0.00 |
| Gibberellin (GA) | 0.58 | 0.02 |
| Root Pruning (RP) | 0.85 | 0.20 |
| GA + RP | 2.95 | 1.08 |

*Preliminary data from a 2-branch cone bud survey in October 1981. Whole tree counts at spring flowering will be utilized for statistical evaluation.

Table 2. Effect of Root Pruning and Gibberellin ($GA_{4/7}$) Treatments on Shoot Growth in Douglas Fir.

| Treatment | Final Terminal Shoot Length (mm) | |
|---|---|---|
| | Trees With Previous Cone Production | Trees With No Previous Cone Production |
| Control | 49.5 | 45.8 |
| Gibberellin (GA) | 48.5 | 52.9 |
| Root Pruning (RP) | 25.5 | 26.5 |
| GA + RP | 31.2 | 35.8 |

## CONTAINER SEED ORCHARD RESEARCH (E.P. 865) S.D. ROSS

The profuse flowering response on potted western hemlock cuttings to $GA_{4/7}$ sprays and water stress applied in 1980 (Forest Research Review 1980/81:5-6), was duplicated for trees similarly treated in 1981. Although cones induced on the 1980-treated cuttings developed normally and set sound seed, tree vigor and subsequent flowering potential were adversely affected, presumably the consequence of too severe and/or improperly timed water stress used in conjunction with $GA_{4/7}$ treatment. Vigor reduction was not serious in the second experiment receiving very close control of water stress. This limitation is currently being investigated in growth-room experiments in cooperation with the Pacific Forest Research Centre, Canadian Forestry Service. High temperature within a heated shelterhouse as a cost-effective alternative to the laborious water stress treatment, is being investigated in a collaborative study with MacMillan Bloedel Limited.

Potted white spruce grafts within the unheated shelterhouse have thus far proven recalcitrant to flower induction by means of $GA_{4/7}$ sprays and water stress treatment. As these treatments are known to work on field-grown spruce trees, the problem is apparently one of improper application of treatments.

## COMPARISON OF 2,2-DIMETHYL $GA_4$, $GA_4$, $GA_7$ AND $GA_{4/7}$ MIXTURE FOR ACTIVITY IN DOUGLAS FIR CONE INDUCTION (E.P. 935.01) S.D. ROSS AND R.P. PHARIS

This study was undertaken to evaluate the 2,2-dimethyl derivative of $GA_4$ (diMe$GA_4$), which in several plant bioassays was found to be up to 100 times more active than the parent $GA_4$. Presumably the methyl groups protect the $GA_4$ from rapid metabolic degradation within the plant and/or improve membrane permeability by making it more lipophyllic. The latter property would be highly advantageous from the standpoint of improved absorption of foliar-applied GAs.

The thesis that diMe$GA_4$ should be more active than $GA_4$ could not be tested because the parent pure $GA_4$ was found to be ineffective, whereas pure $GA_7$ was effective in the promotion of Douglas fir flowering. An equally interesting discovery is that the "active" and "inactive" components of the commerical $GA_{4/7}$ mixture may be interacting synergistically. The flowering response to $GA_{4/7}$ mixture (169%) was greater than the sum of the individual responses to $GA_7$ (121%) and $GA_4$ (0%).

## HORMONE FORMULATIONS AND APPLICATION TECHNIQUES (E.P. 935.02) S.D. ROSS

For many conifers, $GA_{4/7}$ in aqueous formulation applied by large droplet sprayers is relatively ineffective in flower promotion, as compared to other, more labor-intensive application methods such as stem injection. Western hemlock is a notable exception, but even with this species the method, albeit cost effective, is wasteful of expensive GAs. Ultra low volume (ULV) spray techniques have been found in many agricultural and other forestry applications to give greater biological control using less chemicals. Even greater efficacy has been achieved by using anti-evaporative oil-based or oil-water suspensions instead of aqueous formulations, which are only poorly absorbed through the waxy cuticle layer surrounding needles and shoots. Preliminary trials, however, had disclosed that certain of these spray oils, which are perfectly safe with angiospermous species, can be highly phytotoxic to conifers.

This study evaluated three proprietary spray oils, propylene glycol, three light weight mineral oils and the standard aqueous $GA_{4/7}$ formulation containing 0.05% Aromox C12W surfactant for phytotoxic effects on Douglas fir, western hemlock and white spruce seedlings. Of these, only the aqueous and propylene glycol formulations of $GA_{4/7}$ were non-phytotoxic. All others caused moderate to severe defoliation and shoot dieback and cannot be considered safe for the operational application of $GA_{4/7}$ or other chemicals (e.g. pesticides, Ethrel) in forestry practice. Propylene glycol should be a more effective carrier for foliar-applied $GA_{4/7}$ than the aqueous formulation, and the flower promotive efficacy of the two formulations will be tested.

## OPTIMIZATION OF $GA_3$ TREATMENT REGIME FOR YELLOW CEDAR AND WESTERN RED CEDAR (E.P. 935.03) S.D. ROSS

Results of this study aimed at determining the optimum $GA_3$ concentration and timing, duration and frequency of application for promotion of flowering in these species are currently being analysed. Positive responses were obtained for both species.

## SUPPLEMENTAL POLLINATION IN A LODGEPOLE PINE SEED ORCHARD AT RED ROCK, 1980 (E.P. 821.03) J.E. WEBBER

With the establishment of several lodgepole pine seed orchards in the interior of British Columbia, trials were initiated on the effects of contaminating sources and seed orchard sources of pollen on seed yields and genetic quality. First experiments tested whether supplemental pollination could increase seed yields and at what stage of receptivity maximum seed yield was obtained. Seven supplemental pollen application periods were tested: 0, 2, 4, 6, 8, 10 and 12 days after female cone bud burst.

At each treatment period, two randomly selected branches were bagged to represent seed yield from non-supplemental pollen sources (controls). Two other branches were pollinated with 0.5 ml of pollen per branch, applied with the booster-pollination wand illustrated in the Forest Research Review 1980/81:7. To test the effect of amount of pollen applied, three levels of supplemental pollen were applied at the 2, 6 and 10 day periods after female cone emergence.

Table 3 shows that supplemental pollination led to a 28% overall increase in filled seeds per cone. Pollen boosting within the first 4 days produced the largest increase in seed yields and only marginal increases thereafter. This was attributed to the high pollen cloud density, from both within and outside the orchard, available to treatment strobili before late boosting. The bulk of pollen shedding (mainly outside orchard sources) was over by the end of the 4 day period.

Table 4 shows that for early treatment, the highest of the three boosting rates, 0.5 ml, produced the largest increases in seed. Quantity of supplemental pollen was of marginal importance when applied late. Results confirm that supplemental pollination of lodgepole pine orchard trees improves yields and genetic quality and demonstrates that operational supplemental pollination should be done within 4 days after female cone bud burst. The largest increases from early treatments were in agreement with observations on Douglas fir (Forest Research Review 1979/80:12-13).

Since natural (contaminating) and seed orchard pollen supplies at the Red Rock seed orchard are abundant, there is little need to add supplemental pollen to increase seed yields alone. However, by boosting early, pollen of known genetic source is in a more favourable position to be entrapped by the pollination drop and subsequently be involved in fertilization. The actual dilution effect of contaminating pollen will be tested in future trials.

Table 3. Effect of Supplemental Pollination on Seed Yields for Lodgepole Pine Treated at Various Periods Beyond Bud Burst.

| Treatment Period | Filled Seeds Per Cone | |
|---|---|---|
| | Control | Boosted |
| Bud burst + 0 days | 0.0 | 7.2 |
| + 2 days | 4.3 | 13.0 |
| + 4 days | 8.8 | 11.8 |
| + 6 days | 19.6 | 20.0 |
| + 8 days | 12.5 | 14.0 |
| + 10 days | 16.9 | 17.2 |
| + 12 days | 14.5 | 15.1 |
| MEAN | 10.9 | 14.0 (28%) |

Table 4. Effect of Supplemental Pollination on Seed Yields for Lodgepole Pine Treated at Various Periods Beyond Bud Burst with Three Levels of Pollen Application.

| Treatment Period | Filled Seeds Per Cone | | | |
|---|---|---|---|---|
| | Control | 0.02 ml | 0.1 ml | 0.5 ml |
| Bud burst + 2 days | 4.3 | 5.8 | 8.8 | 12.0 |
| + 6 days | 19.6 | 20.4 | 24.6 | 20.0 |
| + 10 days | 16.9 | 15.1 | 15.8 | 17.2 |

## THE POLLINATION MECHANISM AND THE OPTIMAL TIME OF POLLINATION IN DOUGLAS FIR (E.P. 899.01) J.N. OWENS

A supplemental study was completed in 1981 to further explain the pollination mechanism. Pollen applied on the first and third days after conelets became receptive was taken into the micropyle in significantly greater quantities than pollen applied at later dates. A second supplemental pollination did not increase the seed efficiency for individual cones. Seeds produced when an average of less than 1.2 pollen grains were taken into the micropyle had essentially the same germination percentage as seeds resulting when an average of 3.4 or more pollen grains were taken into the micropyle.

## SEED ORCHARD CROWN MANAGEMENT (E.P. 944) S.D. ROSS

The need for an effective method for controlling height growth of seed orchard trees is well recognized. Under the favorable growing environment that most orchards provide, the flowers and cones in the upper part of the crown rapidly become inaccessible for efficient and economical harvesting, for protection against pests and cold temperatures, and for pollen management to ensure maximum genetic quality of seeds produced. Hormonal cone induction treatment of large trees is also more difficult.

Working plans were prepared and studies initiated in late winter of 1982 to evaluate top pruning and within-crown branch thinning for effectiveness in controlling height and enhancing cone production in Douglas fir and western hemlock seed orchards. Two approaches to crown management are being investigated for each species. One involves treatment of older orchards where the trees have already reached or are rapidly approaching the maximum height for economical harvesting of cones. Here the objective is to control height without sacrificing seed production. The second approach involves crown training beginning at a relatively early age in order not only to prevent the trees from ever attaining an unmanageable size, but also to shape the crown to provide a branch architecture more conducive to abundant flowering.

## PUBLICATIONS

Haeussler, C. and S.D. Ross. 1981. Container seed orchard research. Proc. Canadian Tree Improvement Association 18th Biennial Meeting, Duncan, B.C. August 17-20, 1981. 5 p. In press.

Owens, J.N., S.J. Simpson and M. Molder. 1981. The pollination mechanism and the optimal time of pollination in Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco). Can. J. For. Res. 11:36-50.

Owens, J.N., S.J. Simpson and M. Molder. 1981. Pollen development and the pollination mechanism of lodgepole pine (*Pinus contorta* Dougl.). Can. J. Bot. 59:1828-1843.

Owens, J.N. and S.J. Simpson. 1982. Further observations on the pollination mechanism and seed production of Douglas fir. Can. J. For. Res. In press.

Owens, J.N., S.J. Simpson and M. Molder. 1982. Sexual reproduction of *Pinus contorta*. II. Postdormancy ovule, embryo and seed development. Can. J. Bot. In press.

Owens, J.N. and H. Singh. 1982. Vegetative bud development and cone initiation in *Abies lasiocarpa*. Can. J. Bot. In press.

Singh, H. and J.N. Owens. 1981. Sexual reproduction of *Abies lasiocarpa* (Hook.) Nutt. Can. J. Bot. 59:2650-2666.

## ACTIVE EXPERIMENTAL PROJECTS

| | | |
|---|---|---|
| E.P. 667 | Spruce scion and rootstock interactions | R. van den Driessche |
| E.P. 738 | Cone initiation and seed development in mountain hemlock | J.N. Owens |
| E.P. 773 | Freeze-drying and viability testing of Douglas fir pollen | J.E. Webber |
| E.P. 799 | Cone induction in Douglas fir and lodgepole pine | J.E. Webber |
| E.P. 821 | Supplemental pollination in Douglas fir seed orchards | J.E. Webber |
| E.P. 830 | Sexual reproduction in *Pinus contorta* | J.N. Owens |
| E.P. 832 | Cone initiation and seed development in *Abies lasiocarpa* | J.N. Owens |
| E.P. 851 | Accelerated growth of seedlings to induce early and abundant cone production | J.E. Webber |
| E.P. 865 | Container seed orchard research | S.D. Ross |
| E.P. 899 | The development of the pollination mechanism in Douglas fir, lodgepole pine and western hemlock and the optimal time for pollination in Douglas fir | J.N. Owens |
| E.P. 900 | Cone initiation and sexual reproduction of *Picea engelmanii* | J.N. Owens |
| E.P. 918 | Mineral nutrition of seed orchard trees | R. van den Driessche |
| E.P. 935 | Hormone treatment methods and regimes | S.D. Ross |
| E.P. 941 | The reproductive cycle of B.C. conifer genera | J.N. Owens |
| E.P. 944 | Seed orchard crown management | S.D. Ross |

## SEED

Operational trials of stratification-redrying of amabilis fir seeds confirmed increased germination rate but revealed that usual improvement in final germination was not obtained on recently collected seedlots of higher dormancy. These seedlots responded best to prolonged wet stratification. Practicability of the stratification-redry system has been enhanced by development of microwave oven techniques for rapid determination of seed moisture.

### THE EFFECT OF SOAKING SEEDS ON GERMINATION OF SOME MAJOR B.C. FOREST TREES (E.P. 835) C. LEADEM

Results show that white spruce, lodgepole pine, and western hemlock seeds germinated about the same whether they were pre-soaked or not. Amabilis fir, Sitka spruce, and Douglas fir seed germination was significantly improved when soaked prior to stratification. Seeds germinated equally well if soaked for 16, 24, or 32 hours, but germination declined slightly if soaked for 48 hours. The effects of different presoaks were not enough to merit changing the standard 24 hour soaking period currently prescribed for B.C. forest tree seeds.

### STRATIFICATION-REDRY OF WHITE SPRUCE (E.P. 848.05) C. LEADEM

White spruce represents almost 50% of the total British Columbia nursery production but germination can be slow or erratic. A solution was sought in a trial of the redrying technique, already proven effective for improving rate and total germination of several true firs.

Ten seed lots were germinated in controlled environment incubators after receiving either of three pretreatments. Seeds were (1) stratified 3 weeks at 2°C with no presoak, (2) stratified 3 weeks at 2°C with 24-hour presoak, or (3) stratified 3 weeks at 2°C with 24-hour presoak, redried to 30% moisture content, and stratified an additional 9 weeks.

Germination of redried seeds was significantly better in only 1 of the 10 spruce lots. In all other lots germination was the same or less than seeds given wet or dry stratification. The major problem with redrying spruce seeds appear to be the mold that develops during prolonged stratification. No further work with stratification-redry of spruce is planned at this time.

### DRYING AND STORING STRATIFIED AMABILIS FIR SEEDS - OPERATIONAL TRIAL AT CAMPBELL RIVER NURSERY, SPRING 1981 (E.P. 848.06) C. LEADEM

The first operational test of the stratification-redry technique was conducted during spring 1981 at the Campbell River Nursery. Ten amabilis fir seed lots were sown in containers after receiving either of three pretreatments. Seeds were soaked for 24 hours and (1) stratified 60 days at 2°C, (2) stratified 90 days at 2°C, or (3) stratified for 30 days at 2°C, redried to 30% moisture content, and stratified an additional 90 days.

As noted in Forest Research Review 1980/81:11, the most notable effect of redrying is the substantial increase in germination rate. At 15 days, redried seeds germinated 26% while treatments (1) and (2) germinated 9% and 10%, respectively. However, improvement in final germination due to stratification - redrying seemed dependent upon the level of dormancy as determined by year of collection. Collections from 1978 again responded to redrying, but 1979 collections being tested for the first time, responded best when stratified either 69 or 90 days. The trial also demonstated that some technical modifications are needed for transfer of the technique to operational scale. Accordingly, the trial will be repeated in spring 1982.

## CONE AND SEED TECHNOLOGY - MICROWAVE OVEN DETERMINATION OF SEED MOISTURE (E.P. 940.01) C. LEADEM

A number of methods have been used for the biologically important measurement of moisture content but no one method has been found completely satisfactory. Preliminary results indicate that a microwave oven can effectively be used to rapidly determine seed moisture content. However, drying times differ depending upon the species and on the level of hydration. Further study is planned to expand and refine the microwave oven technique for general research and operational use.

## PUBLICATIONS

Leadem, C.L. 1981. Seed technology for seed orchards - Seed testing. Proc. Canadian Tree Improvement Association 18th Biennial Meeting, "Seed orchards and strategies for tree improvement", Duncan, B.C., August 17-20, 1981. 24 p. In press.

## ACTIVE EXPERIMENTAL PROJECTS

| | | |
|---|---|---|
| E.P. 835 | The effect of soaking seeds on germination of some major B.C. forest trees | C. Leadem |
| E.P. 838 | Quick test to determine seed quality | C. Leadem |
| E.P. 843 | Seed sizing: Determination of the size range and vigor of screened fractions | C. Leadem |

| | | |
|---|---|---|
| E.P. 848 | Improving seed performance | C. Leadem |
| E.P. 873 | Effect of cone storage on seed viability | C. Leadem |
| E.P. 874 | The relationship between 1/2 cone count and seed yields in white spruce | C. Leadem |
| E.P. 909 | Pelleting tree seed to improve sowing precision and efficiency | C. Leadem |
| E.P. 940 | Cone and seed technology development | C. Leadem |

## NURSERIES, STOCK QUALITY AND PRE-PLANTING TREATMENT

Three nursery physiologists were recruited to permanent status, Dr. Nigel Burdett and Dave Simpson after lengthy careers as contractors and auxiliaries. Simpson has assumed duties as resident physiologist at the new Kalamalka Research Station and Seed Orchard. Dr. Wolfgang Binder will specialize in systems for measurement and control of autumn dormancy, pre-conditioning and storeability for optimization of condition at planting.

Gains continue to be made in nursery planting stock quality having increased survival and growth potential. Reducing seed bed density increases stock quality and practical methods of precision sowing continue to be sought. Improved nursery performance of ponderosa pine and Douglas fir grown at reduced densities was reflected in improved field performance over the one and two seasons, respectively, tested to date. Lodgepole pine can be pelleted and fall sown to achieve precision spacing.

Polyethylene bedhouses increased germination, seedling size and rootmass of white spruce. Increased rootmass is strongly correlated with reduction of frost heaving, a common problem in British Columbia bare root nurseries. Sheeting could not be spread directly over nursery seedbeds.

Modifications of chemical root pruning techniques developed for container grown lodgepole pine have been fully effective for Douglas fir, Sitka spruce, western hemlock and western red cedar. Operational trials on lodgepole pine are described under SX 81212Q on page 119.

White spruce planting stock trials ranked large PSB 415 container seedlings, smaller containers, transplanted bare root, and normal 2+0 bare root in descending order of survival (range 99% to 42%). Stock ranked in similar order for first year height growth, though the growth of some transplanted stock approached that of the container stock.

## OXIDIAZON LEVELS, WEED CONTROL AND CROP DAMAGE (E.P. 693.25)

R. VAN DEN DRIESSCHE

In a previous experiment (E.P. 693.21) oxadiazon, marketed in granular form as Ronstar G, was found to be an effective herbicide in the nurseries. Unfortunately it severely damaged conifer seedling crops at the concentrations employed (2-5.2 kg a.i./ha), except for western red cedar. To test whether newly germinated conifers might tolerate lower, still herbicidally effective concentrations, 0, 0.5, 1.0, 1.5 and 2 kg a.i./ha it was applied at either sowing or 28 days post germination. When oxadiazon was applied after germination prometryne was applied at sowing. A prometryne plus propazine treatment was also included in the experiment, which was conducted at both Koksilah and Surrey nurseries.

Weeding time was reduced 74% over the whole summer by 1.5 kg a.i./ha of oxadiazon applied immediately after sowing, but only western red cedar tolerated this treatment. Oxadiazon applied 28 days after germination was not an effective herbicide. Prometryne, applied immediately after sowing, reduced weeding time at Koksilah about 35% and at Surrey about 60%. It did not reduce seedling densities or dry weights. Thus oxadiazon is safe for use on western red cedar at 1.5 kg a.i./ha immediately after sowing, but it is not as suitable as prometryne at 0.56 kg a.i./ha immediately after sowing for the other species.

## SPACING OF SEED IN NURSERY BEDS WITH THE NIBEX DRILL (E.P. 786.06)

R. VAN DEN DRIESSCHE

Other work conducted under E.P. 786 has shown that reducing seedbed density improves stock quality. In these experiments density was reduced by thinning 1+0 seedling nursery beds. It would clearly be more economical if the right amount of seed could be sown to produce the required density. A Swedish single row hand drill (Mini Nibex), designed to sow different types of seed over a range of spacings, was obtained and used in an experiment conducted at four nurseries: Koksilah, Campbell River, Surrey and North Road. The purpose of the experiment was to determine the relationship between seed sowing rate and 2+0 stand denstiy and to further relate seedling density to performance after outplanting.

Seed was sown at six nominal spacings: (1) 1.2 cm, (2) 2.0 cm, (3) 4.0 cm, (4) 8.0 cm, (5) 12 cm and (6) control, approximately 0.5 cm. Seed counts were made immediately after sowing and densities of 1+0 and 2+0 seedlings were determined. The number of 2+0 Douglas fir plants as a percentage of the number of seeds sown (plant %) was 33% at North Road and 36% at Koksilah, both heavy soil nurseries. Douglas fir plant % at Campbell River was 69% and at Surrey 65%. Much of the loss occurred during the first year, and was due to Fusarium wilt. Counts showed 35% mortality at North Road, 18% mortality at Koksilah, 10% at Surrey and none at Campbell River. Sitka spruce, white spruce, interior Douglas fir and western red cedar, grown in this experiment were apparently not so severely affected although none of these species were grown at North Road.

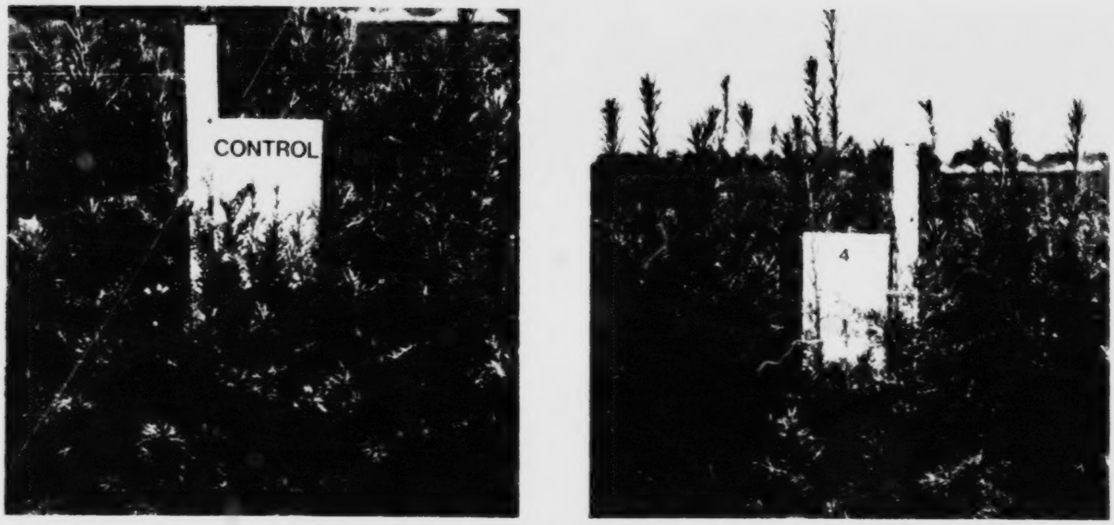

Plate 1. Two-year old Douglas fir grown at different spacings in Surrey Nursery. Control spacing was 1.5 cm and treatment 4 spacing was 6.5 cm at the end of the 1+0 year (E.P. 786.06).

Plate 2. Two-year old white spruce grown at different spacings in Surrey Nursery. Control spacing was 2 cm and treatment 2 spacing was 4 cm at the end of the 1+0 year (E.P. 786.06).

Some nursery growth responses to reduced seedbed densities are illustrated in Plates 1 and 2. Morphological and root growth capacity measurements have been obtained for all five species grown over a range of seed bed densities. Representative samples are being planted out at four suitable sites. Subsequent survival and growth will be related to seed bed density and seedling characteristics.

## OVERWINTER SOWING OF SEED PELLETED BY HILLESHÖG (E.P. 786.07, 11)

R. VAN DEN DRIESSCHE

Precision sowing in the nursery permits regular spacing of seedlings so that a uniform crop can be grown at optimum spacing. Several methods for achieving precision sowing have been developed elsewhere. One widely used in horticulture is to coat seeds with an inert material so that the resulting pellets are uniform spheres. These can then be separated and sown individually by special machines. Most pelleting techniques depress germination of conifer seed, but the Swedish Company Hilleshög is developing a pelleting technique for conifer seed and pelleted some Douglas fir, Sitka spruce, white spruce and lodgepole pine seed for testing.

Unstratified, pelleted seed of the four species was fall sown, together with unpelleted seed of the same seed lots, at Koksilah and Surrey nurseries, using the Nibex drill. Known quantities of seed were also fall sown by hand at North Road nursery. Pelleted lodgepole pine and white spruce seed germinated as well as unpelleted seed the next spring. Pelleting depressed germination of Douglas fir and Sitka spruce. Overwinter losses of Sitka and white spruce seed was large. Pelleting had little effect on seedling size. Only lodgepole pine seed could be satisfactorily pelleted and fall sown by this method at present.

## SEEDBED DENSITY EFFECTS ON DOUGLAS FIR SEEDLING MORPHOLOGY, PHYSIOLOGY, AND FIELD PERFORMANCE (E.P. 836.02) D.G. SIMPSON

Lower seedbed densities resulted in more massive, but not taller 2+0 Douglas fir seedlings. Root regeneration potential and tissue nutrient content was not influenced by seedbed density. If nursery grading standards are increased to 150 mm shoot length and 4 mm root collar diameter, nursery production could be improved by increasing seedling spacing to 24 mm between individuals in the drill row. Growth of seedlings outplanted on a forest site was significantly improved at the lowest seedbed density, both in the first and second year after outplanting (Table 5).

Table 5. Terminal shoot growth, in the first and second season after outplanting, of 2+0 Douglas fir seedlings grown at four seedbed densities.

| | Seedbed density/m$^{2}$* | | | |
|---|---|---|---|---|
| | 259 | 172 | 118 | 74 |
| First Season Shoot Growth (mm) | 55$^{b}$ | 55$^{b}$ | 64$^{ab}$ | 75$^{a}$ |
| Second Season Shoot Growth (mm) | 85$^{b}$ | 90$^{b}$ | 105$^{ab}$ | 125$^{a}$ |

*Density at end of second nursery growing season

Means followed by same letter are not significantly different at the .05 level of confidence

## SEEDBED DENSITY EFFECTS ON DOUGLAS FIR AND PONDEROSA PINE SEEDLING MORPHOLOGY, PHYSIOLOGY, AND FIELD PERFORMANCE (E.P. 836.06) D.G. SIMPSON

Improved field performance (Table 6) and seedling morphology resulted from seedbed density reduction in ponderosa pine seedlings. Douglas fir seedling field performance was not consistently improved by reduced seedbed density.

Tissue nutrient content and root regeneration levels were largely unaffected by seedbed density.

Table 6. First outplanting year survival and growth of 2+0 bareroot Douglas fir and ponderosa pine seedlings grown at four seedbed densities.

| | Seedbed density/m$^{2}$* | | | |
|---|---|---|---|---|
| | 290 | 240 | 160 | 80 |
| Douglas fir | | | | |
| Survival (%) | $90^{a}$ | $90^{a}$ | $93^{a}$ | $88^{a}$ |
| Growth (mm) | $55^{b}$ | $63^{a}$ | $63^{a}$ | $58^{ab}$ |
| Ponderosa pine | | | | |
| Survival (%) | $80^{b}$ | $88^{ab}$ | $93^{a}$ | $94^{a}$ |
| Growth (mm) | $52^{c}$ | $74^{a}$ | $65^{b}$ | $77^{a}$ |

*Density at six weeks after sowing

Means followed by same letter do not differ at the .05 level of confidence

## SLOW RELEASE FERTILIZERS FOR DOUGLAS FIR AND INTERIOR SPRUCE AT SURREY NURSERY (E.P. 640.77) R. VAN DEN DRIESSCHE

Slow release fertilizers should provide a steadier supply of nutrients to nursery seedlings than soluble fertilizers. Another advantage is that they need only be applied once or twice per crop rotation, but soluble fertilizers must be applied as often as once every 14 days during the growing season. In practice, however, seedling growth responses to slow release fertilizers are variable, probably due to annual weather differences. In a previous experiment (E.P. 640.66, Forest Research Review 1979/80) the slow release fertilizer osmocote resulted in greater growth of interior spruce than was obtained with ammonium sulphate. In this experiment further testing was continued using ammonium phosphate, urea formaldehyde, sulphur coated urea, osmocote and ammonium sulphate. These fertilizers were applied to seed beds of Douglas fir and interior spruce at Surrey nursery at 0, 70, 140 and 210 kg N/ha per year. Two methods of application, banding and broadcasting, were used. In the second year the same fertilizer rates were reapplied as broadcast treatments. All plots, except those receiving AMP, received a basal dressing of calcium superphosphate supplying 80 kg P/ha, and two top dressings of 60 kg K/ha were made to the entire experiment.

Preliminary analysis shows that ammonium phosphate and ammonium sulphate produced the largest Douglas fir seedlings and that ammonium phosphate produced the largest spruce seedlings. Response to ammonium phosphate continued up to 210 kg N/ha per annum in both species.

## POLYETHYLENE SEEDBED COVERS AFFECT GERMINATION, MORPHOLOGY, AND FROST HEAVING LOSSES OF 1+0 WHITE SPRUCE SEEDLINGS (E.P. 836.08) D.G. SIMPSON

In uncovered seedbeds at Red Rock nursery, an average 59% of the viable seed sown in two white spruce seed lots germinated. Polyethylene covered bedhouses significantly increased germination to 71%, while clear 4 mm polyethylene sheeting spread directly on the seedbed reduced germination to 25% of the viable seed sown. Black or white polyethylene did not significantly affect total germination (Figure 1).

Seedlings grown under the bedhouses were somewhat larger and root masses were significantly greater than those seedlings from the control and polyethylene covered plots. This is an important treatment response as there was a highly significant negative linear correlation between frost heaving losses and seedling root mass, in a year in which disastrous losses occurred at Red Rock nursery (Figure 2).

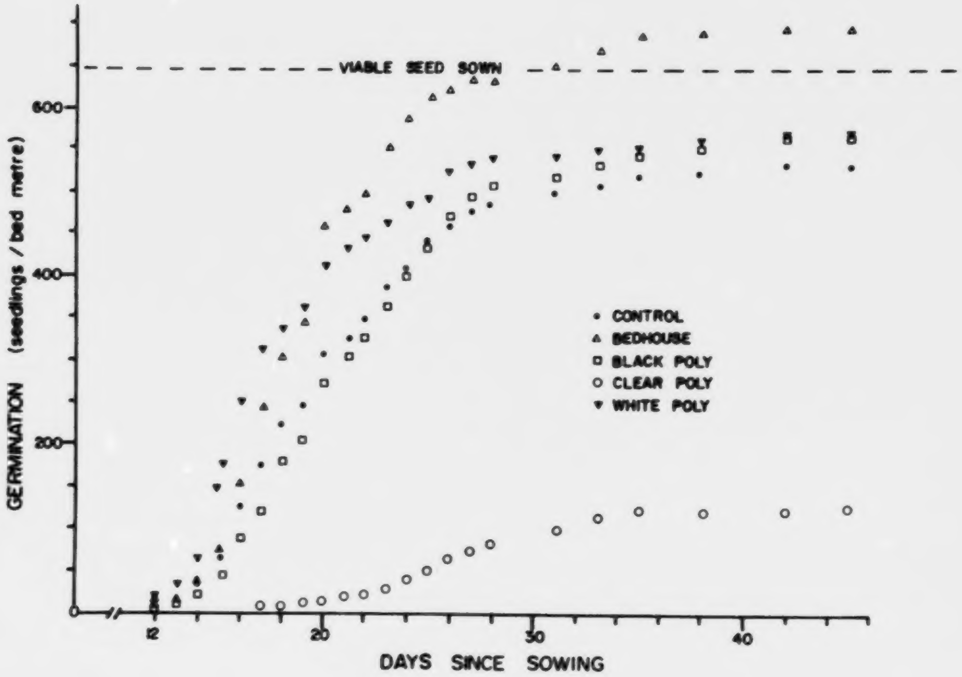

Figure 1. Effects of bed covering on white spruce germination, seedlot 1931.

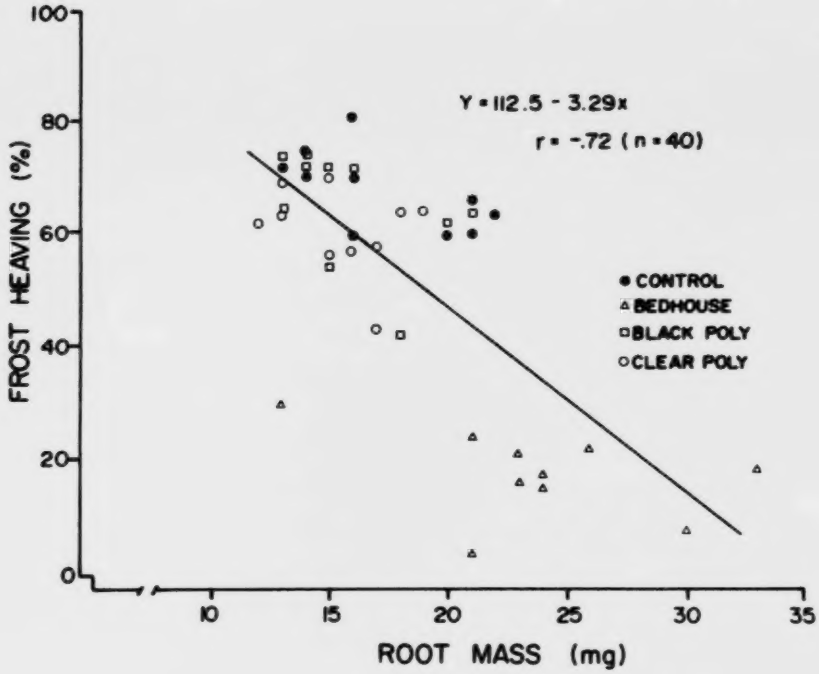

Figure 2. Correlation between frost heaving and root dry mass of 1+0 white spruce seedlings.

PRODUCTION OF CONTAINER GROWN CONIFER SEEDLINGS IN SEWAGE SLUDGE COMPOST (E.P. 877.02) D.G. SIMPSON

Composted sewage sludges, from three municipalities in British Columbia, were used as growing media for Douglas fir and lodgepole pine PSB 211 seedlings.

Compared to the 3:1 limed peat/vermiculite mix presently used in B.C. Ministry of Forests nurseries, sewage sludge composts, even with the addition of vermiculite, failed to produce seedlings of equal quality.

It may be possible to reduce the observed quality difference by the manipulation of fertilizer and irrigation regimes during the growing season. Root regeneration levels of seedlings cold stored for 90 days was shown to be greater in some of the sewage sludge treatments compared to the standard peat/vermiculite mix.

Operational use of sewage sludge composts is not recommended for container nurseries unless the cost or supply of the presently used sphagnum peat moss becomes limiting.

## CHEMICAL CONTROL OF ROOT MORPHOGENESIS IN CONTAINER SEEDLINGS (E.P. 791) and AN EVALUATION OF NEW METHODS FOR THE PRODUCTION OF FOREST PLANTING STOCK (E.P. 858) A.N. BURDETT

The chemical root pruning technique developed for use with lodgepole pine (Forest Research Review 1979/80:25-26) has been tested with nine other conifers from six genera. It was entirely effective with Scots pine. After modification of the method of treatment it was also fully effective with Douglas fir, Sitka spruce, western hemlock and western red cedar. Factors found to influence the success of the treatment include: container size; the concentration of cupric carbonate (the root pruning agent) in the container wall coating; and the chemical and physical properties of the growing medium. It is anticipated that, with further modification of the treatment method, the technique can be made applicable with most conifers.

As an alternative to the chemical root pruning technique, roots of container grown seedlings can be box pruned mechanically. An experimental system for doing this is illustrated in Plate 3.

Stock is being grown for a series of field trials intended to reveal the effect of root pruning on the survival and growth of planted Douglas fir, western hemlock, western red cedar and interior spruce. Both chemical and mechanical techniques will be used for box pruning the roots of the trees.

An operational trial of the chemical root pruning treatment was carried out with lodgepole pine at five nurseries. For information on the results of this trial see page 119 (SX 81212Q).

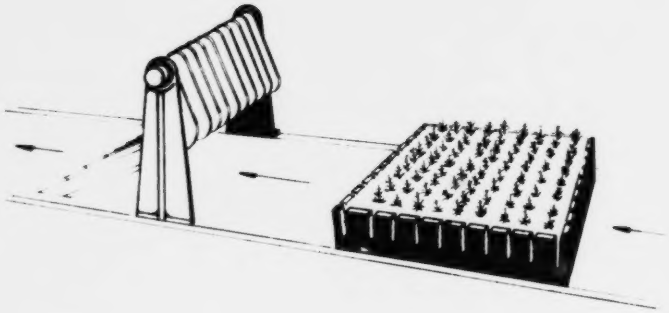

Plate 3. A mechanical system for box pruning the roots of container grown stock. Design by D.K. Garthwaite. Drawing by H.M. Cooke.

## INTERACTION OF SPACING AND WRENCHING ON SEEDLING SIZE AND QUALITY (E.P. 786.05) R. VAN DEN DRIESSCHE

Interior spruce seed lot 1856 was sown at Surrey nursery in May 1979, and spacing treatments were imposed in August of the same year by hand thinning. Spacing treatments were: (1) control (the nursery sowing density), (2) 2 cm spacing and (3) 5 cm spacing. By August 1980, actual spacings in the drill were as follows: (1) 1.4 cm, (2) 2.8 cm, and (3) 5.8 cm. Undercutting was applied factorially to the three levels of thinning during the second year of growth in the nursery. Undercutting treatments were (1) no undercuttng (2) undercutting at monthly intervals July to September, (3) undercutting at monthly intervals May to September. The Marsh undercutter was used on most occasions at a depth of about 15 cm. The aim was to cut at between 5 and 10 cm, but such shallow undercutting tended to uproot stock and destroy the bed.

Losses due to culling to the Silviculture Branch standard of 15 cm height and 2.6 mm diameter were 14% at control and 2 cm spacing, but 25% at 5 cm spacing. Heavy losses in yield due to more stringent culling at 5 cm spacing are probably due to the height component. Height in the nursery was significantly reduced at 5 cm spacing.

Root collar diameter, seedling dry weight and root/shoot weight ratio were increased by wider spacing along a curve of diminishing returns. Undercutting increased both root dry weight and root/shoot weight ratio. However, undercutting from May to September reduced shoot and seedling dry weight.

Two hundred trees were lifted from each plot on November 19, 1980, stored in a freezer and then planted at Wansa Lake, Prince George, in May 1981. The two hundred trees in each treatment were planted in plots of 50 in four randomized blocks.

After one growing season survival averaged 92% and was unaffected by treatment. The trees looked chlorotic and were nutrient deficient judging by colour and growth responses of trees in an adjacent fertilizer experiment on the same site. Height growth and relative growth rate (RGR) were significantly increased by each increase in spacing. The 5 cm spacing treatment in the nursery increased first season height growth 2.7 cm (43%) over control. This effect is admittedly small, but the fairly large differences in shoot length RGR imply that the height growth of spaced seedlings will continue to increase in relation to control.

Undercutting had no effect on seedling growth in the field despite the fact that it increased root mass in the nursery. Undercutting at the depth and frequency used in this experiment has so far shown no benefit.

## SUITABLE INTERIOR SPRUCE STOCK TYPES AND QUALITY FOR REFORESTATION (E.P. 859.01) R. VAN DEN DRIESSCHE

Production of a variety of different types of interior spruce stock was described under this E.P. number in the Forest Research Review 1980/81. The stock was produced at Surrey and Red Rock nurseries and included two seed lots. It was planted on a recently logged site in the McGreggor River area of the Prince George Forest Region at the end of May 1981. Survival ranged from 99% for 1+0 PSB 415 to 42% for normal nursery 2+0 BR. Container stock survived better than bare root stock and transplanted bare root survived better than seedling bare root. Larger container seedlings survived better than smaller ones. First year height growth of some bare root transplants was almost as great as that of container seedlings.

## USE OF ANTITRANSPIRANTS TO CONTROL WINTER DESICCATION AT SURREY NURSERY (E.P. 827.03) D.G. SIMPSON

Due to mild winters both in 1980/81 and 1981/82, there has been little winter desiccation in antitranspirant treated or untreated plots. Samples of seedlings treated in 1980/81 were outplanted and grown for one field season; no significant height growth effects were found (Table 7). Measurement of root regeneration potential and plant moisture stress after one week of 30°C day/25°C night, 400 $\mu$ Em$^{-2}$s$^{-1}$, and 75% relative humidity conditions, also failed to show any treatment effects on either root regeneration or plant moisture stress in both 1980/81 and 1981/82.

It is, therefore, supposed that film forming antitranspirants applied to 1+0 Douglas fir bareroot seedlings in early winter will be sufficiently weathered, so not to have adverse effects on seedling field performance or post storage physiology.

Table 7. First field season shoot growth of 1+0 Douglas fir bareroot seedlings sprayed with several film forming antitranspirants.

| Antitranspirant | Shoot growth (mm) |
|---|---|
| XEF-4-3561-A | 158 |
| Wilt Pruf | 156 |
| Folicote | 170 |
| Clearspray | 185 |
| Vaporgard | 160 |
| Control | 161 |

Not significantly different at the .05 level of confidence.

## EFFECTS OF ANTITRANSPIRANTS ON STORABILITY, DROUGHT RESISTANCE, AND FIELD PERFORMANCE OF CONIFER SEEDLINGS (E.P. 827.04) D.G. SIMPSON

Storability, considered as a ratio of pre- to post-cold storage root growth capacity (RGC), was not affected by any of the film forming antitranspirants tested. A possible reduction of gray mould (Botrytis spp.) on some of the antitranspirant treated seedlings was noted, but this observation must be confirmed by further experiments.

The antitranspirants XEF-4-3561-A, Wiltpruf, Folicote, and Vaporgard significantly reduced predawn plant moisture stress (PMS) of lodgepole pine, white spruce, western hemlock, and Douglas fir PSB 211 seedlings growing under favorable conditions. Seedlings sprayed with the other two antitranspirants tested, Plantgard and Clearspray, did not have predawn PMS levels higher than unsprayed seedlings.

Under drought avoidance test conditions, white spruce seedlings treated with the antitranspirant XEF-4-3561-A required nine days to reach the same PMS levels as untreated seedlings. Wiltpruf and Vaporgard treated seedlings "avoided drought" for only five days, while Folicote, Plantgard, and Clearspray were ineffective in aiding white spruce seedlings to avoid drought.

Survival of outplanted lodgepole pine seedlings was not affected by antitranspirant treatment. However, survival of white spruce seeedlings treated with Vaporgard, XEF-4-3561-A, or Wiltpruf was reduced to 91%, compared to 99% for untreated seedlings. Compared to untreated seedlings, Wiltpruf significantly increased first season growth of lodgepole pine seedlings from 96 mm to 107 mm. In white spruce, however, Wiltpruf and XEF-4-3561-A both decreased first season growth from 51 mm to 45 and 44 mm, respectively.

Film forming antitranspirants, in particular XEF-4-3561-A, Wiltpruf, Vaporgard, and possibly Folicote, can be shown to reduce PMS without unduly adverse effects on seedling field performance or physiology. However, the operational use of antitranspirants as agents to increase the drought avoidant abilities of the conifers most commonly planted in British Columbia does not appear justified.

## CONDITIONING/FERTILIZER TRIAL: RED ROCK, SKIMIKIN, SURREY, AND CAMPBELL RIVER NURSERIES (E.P. 866.01-04) D.G.M. DONALD AND D.G. SIMPSON

Analysis of first growing season field performance data for several species on five of eight plantations support the following general conclusions:

1. Height growth in first field season:
    a) Shallow conditioning (undercutting) in the nursery reduces height growth of planted seedlings.

   b) 4-12-8 fertilizer applied at 1.25 g per seedling 50 days prior to lifting increases first season height growth.
   c) Planting seedlings with their root collars 5 cm below the soil surface increases first season height growth.

2. Survival in first field season:
   a) Shallow conditioning in the nursery improved survival in only one seedlot (Picea glauca from Surrey)
   b) 4-12-8 fertilizer applied at 2.5 g per seedling 50 days prior to lifting reduced survival. Applications at 1.25 g per seedling had no effect on survival in four of five plantations.
   c) Planting seedlings with their root collars 5 cm below the soil surface increased survival in one plantation and had no effect in the others.

Second and third year field survival and growth data will be collected in 1982 to be included in a final report(s) terminating this experiment initiated by Dr. D.G.M. Donald of the University of Stellenbosch, South Africa.

## PREDICTING STORABILITY OF WHITE AND ENGELMANN SPRUCES FROM FOUR B.C. NURSERIES (E.P. 869.01) D.G. SIMPSON

Storability, defined as a ratio of post- and pre-storage root growth capacity, was not found to be consistently correlated with stem impedance ratio, a measure of seedling frost hardiness. However, impedance ratio was found to be related to field performance. Ratios of impedance, made before and after -19°C freezing, should be greater than 0.70 before seedlings are lifted for storage.

If calendar date lifting windows are to be used to schedule lifting, the present practice of fall lifting white and Engelmann spruces for -2°C overwinter storage after mid-October seems suitable at the four nurseries considered: Surrey, Chilliwack, Skimikin, and Red Rock. Spring lifting for storage, rather than hot planting, is an undesirable cultural practice resulting in poor field performance.

Seedling size characteristics could not be considered alone as an indication of field performance potential. While considerable nursery variation exists in both seedling morphology and physiology, all four nurseries have the potential to produce similar quality seedlings.

## THE EFFECT OF DAYLENGTH AND TEMPERATURE REGIME ON BUD DORMANCY, FROST HARDINESS, AND STORABILITY OF PICEA SPP. SEEDLINGS (E.P. 869.03) D.G. SIMPSON AND D. MACY

Actively growing interior spruce seedlngs were placed into five conditioning environments: warm/short, warm/long, cool/short, cool/long, and natural conditions. Seedling samples were taken at fortnightly intervals over a twelve-week period and assessed for:

1. mitotic activity of terminal apicies and stage of bud development,
2. frost hardiness,
3. root regeneration potential at initial sampling and again after 6- and 24-week +2°C storage.

Reports will be prepared on the influence of temperature and daylength on terminal bud development, mitotic activity, development of frost hardiness, and root regeneration potential as well as the relationship between these variables and their usefulness as predictors of post storage seedling quality.

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## ACTIVE EXPERIMENTAL PROJECTS

| | | |
|---|---|---|
| E.P. 640 | Requirements of conifer seedlings for mineral nutrients | R. van den Driessche |
| E.P. 643 | Prediction of nutrient status in Douglas fir by foliar analysis | R. van den Driessche |
| E.P. 652 | Dormancy and frost hardiness | R. van den Driessche |
| E.P. 693 | Test of Triazine, Carbamate, and other compounds as nursery herbicides | R. van den Driessche |
| E.P. 747 | Cold storage of conifer nursery stock | R. van den Driessche |
| E.P. 786 | Seedbed density and seedling spacing | R. van den Driessche |
| E.P. 791 | Chemical control of root morphogenesis in container seedlings | A.N. Burdett |

| | | |
|---|---|---|
| E.P. 827 | Root dipping treatments | D.G. Simpson |
| E.P. 836 | Interior Douglas fir nursery stock problems at the Skimikin nursery | D.G. Simpson |
| E.P. 846 | The effects of undercutting and wrenching in the nursery on seedling quality | R. van den Driessche |
| E.P. 858 | An evaluation of new methods for the production of forest planting stock | A.N. Burdett |
| E.P. 859 | Early growth and survival of interior spruce stock types | R. van den Driessche |
| E.P. 866 | Conditioning/fertilizer trials in 2+0 nursery stock | D.G. Simpson |
| E.P. 869 | Seedling quality research | D.G. Simpson |
| E.P. 877 | Production of bare root nursery stock on composted sewage sludge | D.G. Simpson |
| E.P. 928 | Quality control in the production of nursery planting stock | A.N. Burdett |
| E.P. 946 | Improving early growth after outplanting | R. van den Driessche |

# SILVICULTURE

## SITE PROTECTION AND REHABILITATION

Logging operations can contribute to two types of soil movement - surface erosion and mass wasting. Landing construction, timber yarding and log transportation often result in removal of topsoil and soil compaction. Site protection and rehabilitation research is aimed at developing practical techniques for establishing vegetative cover on severely disturbed forest soils in order to help prevent further site degradation, restore site productivity where feasible and to protect other resource values.

In 1981/82, research continued with increased emphasis on the application of techniques in forest operations and on providing research extension services for field personnel. A cooperative project with Engineering Branch is underway to design and construct an improved aerial hydroseeding device. The collection, propagation and outplanting of native shrub species continued. New test plots were established in the central interior to study soil improvement with nitrogen-fixing plants as a possible strategy for landing rehabilitation. In the Cariboo Forest Region, landing and skid road disturbances were monitored, assessed and recommendations made for restoring site productivity.

### REHABILITATION OF LANDINGS AND SKID TRAILS (E.P. 777) A. VYSE

A land survey was carried out in the fall of 1981 to assess whether the Cariboo Forest Region landing policy of 1978 was being applied and whether its terms required modification. The policy specified conditions for landing construction, operations, slash disposal and rehabilitation.

The survey assessed landings in the Interior Douglas Fir (b) Biogeoclimatic Subzone (IDFb) and the Sub-Boreal Spruce (SBS) Biogeoclimatic Zone. Time limitations restricted the scope of the survey, however, cutblocks were selected to cover several operators over a wide geographical range.

The survey found:

1. Poor location selection which necessitated excessive site disturbance to produce a working surface.

2. A loss of site nutrients since the topsoil was removed and seldom respread.

3. Slash disposal by burning conformed to the regional policy except where dirty piles reduced the effectiveness of the burn.

4. Scarification did not conform to the regional policy in the IDFb Subzone since only 8% of the landings were treated. Ninety percent of the SBS Zone landings had been scarified.

5. Compaction was significantly reduced at the soil surface by scarification. Compaction below the depth of scarification was not reduced. Burn piles had the greatest depth of uncompacted material.

6. Winter landings often required rehabilitation contrary to current practice.

7. Grass seeding produced fair to good results; scarification improved the catch. Burn piles produce the best grass catch and production.

8. Planted spruce did not appear healthy and was not growing well. This was attributed to the lack of nutrients and degree of compaction on the landings.

A number of recommendations were made to improve the chances of restoring site productivity on landings.

### HYDROSEEDING LOGGING ROADS FOR STABILIZATION AND RESOURCE PROTECTION (E.P. 818) S.G.J. HOMOKY

During the 1981 field season the range of test sites was expanded to include the Boreal White and Black Spruce (BWBS) Biogeoclimatic Zone in the Dawson Creek Forest District. In the Interior Douglas Fir (IDF) Zone, the Grizzly Swamp Irrigation Dam site was treated in cooperation with Vernon Forest District staff. A small test site located in the Engelmann Spruce - Subalpine Fir (ESSF) Zone, Quesnel Forest District, was installed as part of a field training program.

Most of the hydroseeding test plots were evaluated for cover establishment and species establishment frequency. The information is being compiled in a case history format. Slope cover recorded in 1980 either remained stable or increased by 5 or 10%. Invasion of native species into the agronomic plant cover was not significant with the exception of red alder on one test site in the Coastal Western Hemlock (CWH) Zone. Two agronomic species, however, started to spread into hydroseeded test sites from adjacent dry-seeded strips at some interior locations. These species are orchard grass, Dactylis glomerata and timothy, Phleum pratense.

In addition to training seminars reported below in E.P. 834, two were given to Ministry of Forests personnel, in Victoria and in Prince George, addressing the entire concept of disturbed forest land rehabilitation. A smaller presentation was given in Port Alberni dealing with the prevention and control of roadside erosion.

## THE REHABILITATION OF SEVERELY DISTURBED FOREST LAND (E.P. 834) W.W. CARR

The first project objective, the control of erosion through vegetation management ran concurrently with E.P. 818. Technology transfer to the operational level gained momentum. Three training seminars were presented in 1981/82 in Prince George, Chetwynd and Nelson. Smaller seminars were given at several district offices. Efforts are being made to assist Ministry of Forests regions and districts as well as forest companies in converting fire equipment for use in hydraulic seeding. In the Prince George Forest Region, a 3 600 ℓ tank was equipped with a new pumping system to provide hydraulic agitation. Testing was supervised by Research Branch personnel. Demand has increased for an aerial hydroseeder unit that can be used for revegetating slides and gullies that are not accessible to ground-based equipment. This prompted a co-operative initiative between the Ministry of Forests Research and Engineering Branches to design a prototype-unit. It is hoped that the new design will include corrective measures to improve the safety aspect of the operation.

At the Spuzzum Forest Road, Chilliwack Forest District, the 1980 seeding and shrub planting areas were assessed. A progress report was prepared for the Vancouver Forest Region, Engineering Section. At the Grizzly Swamp Irrigation Dam site, Vernon Forest District, assistance was provided to district staff in the planning and revegetation phases of the project. Two hectares were hydroseeded.

The second program objective is to study the recovery of the productive capability of severely disturbed soils through vegetation establishment. Findings to date at the Koksilah test site (E.P. 834.03) indicate a substantial response in conifer seedling height growth to grass-legume presence. New trials were established south of Vanderhoof in June, 1981 to examine the use of legumes in land rehabilitation (E.P. 834.07).

## THE PROPAGATION AND ESTABLISHMENT OF TREE AND SHRUB SPECIES FOR EROSION CONTROL (E.P. 863) C.J. MARCHANT

This project is designed to provide methodology for the propagation and outplanting of native woody plants suitable for soil stabilization and disturbed site rehabilitation in coastal and southern interior British Columbia.

Collection sites for a range of provenances and species have been established at elevations between 0 and 1 600 m above sea level in natural habitats.

Four propagation facilities are now in use: at the Botanical Gardens of the University of British Columbia, the Chilliwack Forest Nursery, Slocan Park, and at Tlell on the Queen Charlotte Islands. Tunnel greenhouses are being constructed at two of these locations.

Hardwood cutting propagation was applied to 18 species of which six were rated successful: survival rates ranged from 5% for Cornus sericea to 92% for Symphoricarpos albus. Some 6 000 shrublets were raised by this method.

Softwood cuttings under mist in the summer of 1981 proved useful for four species. Sometimes more sophisticated facilities and handling techniques are needed for softwoods than for hardwoods.

Seed from 35 shrub species was germinated in spring following stratification, producing 2 735 coastal container plants and 2 600 interior plants. These plants overwintered outdoors in plunge beds or cold frames. Collection of seed from 45 species extended from 22 July to December 16, followed by extracting, cleaning, intensive pre-germination and stratification procedures through the winter months. For many species this is the most efficient, though slower propagation method. Special attention is being applied to desirable, but difficult to propagate, nitrogen fixing species such as Ceanothus and Shepherdia.

Outplanting on test sites continued on the Queen Charlotte Islands, on Vancouver Island, in the Fraser Canyon and near Nelson. Survival and establishment are promising. Joint field projects with Fish and Wildlife Branch, Ministry of Environment, B.C. Forest Products Ltd. and Queen Charlotte Island Fish/Forestry Interaction Program are underway.

## PUBLICATIONS

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Homoky, S.G.J. 1982. The rehabilitation of disturbed forest land. Proceedings of the Sixth Annual British Columbia Mine Reclamation Symposium in Vernon, B.C. (in press).

## ACTIVE EXPERIMENTAL PROJECTS

| | | |
|---|---|---|
| E.P. 777 | Rehabilitation of landings and skid trails | A. Vyse |
| E.P. 818 | Hydroseeding logging roads for stabilization and resource protection | S.G.J. Homoky |
| E.P. 834 | The rehabilitaton of severely disturbed forest lands | W.W. Carr |
| E.P. 863 | The propagation and establishment of tree and shrub species for erosion control | C.J. Marchant |

## FOREST REGENERATION

Regeneration research includes a variety of projects related to stand establishment and early tree growth. Most of the studies can be classified under five categories: species and stock type trials, plantation performance studies, site preparation, regeneration methods, and cone and seed production.

Species and stock type trials compare the survival and growth performance of several tree species and stock type options, especially on sites which are difficult to restock. Plantation performance studies aim for development of standards for the evaluation of plantation height growth. Site preparation studies evaluate the effect of different site preparation methods on survival and early growth. Regeneration methods evaluate the suitability of natural and artificial regeneration and compare the results of alternative planting stock and planting techniques. Cone and seed production studies are concerned with monitoring availability of tree seed.

Research in ecophysiology has recently been initiated in the interior of the Province. Ecophysiology is concerned with studying changes in the structure and function of plants in relation to environmental conditions. The project in progress investigates the physiological and environmental determinants of growth repression in lodgepole pine. Another project dealing with the post-planting ecophysiology of interior spruce was initiated.

### CONE CROP PERIODICITY IN SPRUCE, NELSON FOREST REGION (E.P. 618)

C.F. THOMPSON

The cone crop in 1981 was very poor, with only two cones on the 56 trees being monitored for this project. Consequently, no cones were collected, and no seed traps were set. A comparison of the germination capacity of seed collected from the 1980 cone crop and from seed traps in spring 1981 showed that the seed trap collected seed had lost viability over winter (80% vs 17%). Both seed collections were examined by J. Sutherland at the Pacific Forest Research Centre. Caloscypha fulgens was found in a small number of the seed trap collections, but none was found in the conventional collection. A large number of seeds in the seed trap collection had decayed over winter. These two factors probably accounted for the overwinter reduction in viability.

## TREE SPECIES TRIAL IN THE KITIMAT VALLEY (E.P. 712) J. POLLACK

The objective of this experiment is to assess the relative suitability of Sitka spruce, western hemlock, lodgepole pine and western red cedar on diverse landforms in the Kitimat Valley. The project was established in May, 1975 on six sites ranging from broadcast burned outwash sites, bladed alluvial sites, broadcast burned morainal blankets and broadcast burned colluvial veneers over bedrock. Soils were Orthic Humo-Ferric Podzols with the exception of the bladed alluvial site which displayed Orthic and Gleyed Dystric Brunisols bordering on sandy Regosols.

The average performance for all sites 6 years after outplanting showed western red cedar with the greatest total height (170.3 cm) followed by lodgepole pine (168.8 cm), western hemlock (138.9 cm) and Sitka spruce (125.3 cm). Species ranking for the periodic annual height increments remained unchanged for the two growth periods 1975-77 and 1978-80. Lodgepole pine averaged 33.7 cm/year for 1978-80 followed by western hemlock (28.0 cm/year), western red cedar (27.2 cm/year) and Sitka spruce (25.4 cm/year).

The sandy Regosol of the bladed alluvial site now supports dense Salix spp. Brush competition and lack of organic material has resulted in poor performance of the three more tolerant species. Lodgepole pine, however, exhibited the best height growth on this site (209.3 cm). The pine has managed to keep pace with brush growth for the first 6 years whereas the other species are overtopped.

At the rapidly drained, broadcast burned colluvial veneer over bedrock site, three of the four species exhibited their poorest growth at any of the six test sites. Survival was also lowest on this site, with 92.7% for lodgepole pine followed by Sitka spruce (92.1%), western red cedar (88.5%) and western hemlock (70.2%).

## HIGH ELEVATION SPECIES AND STOCK TYPE TRIALS (E.P. 759) J.T. ARNOTT AND F.T. PENDL

This cooperative research project of the Pacific Forest Research Centre and the Research Branch has been previously reported in the Forest Research

Reviews 1979/80:38 and 1980/81:28. Results presented here are drawn from part of phase II of the project in an attempt to tentatively identify which of the three stock types - 1+0 plug (PSB 211), 1+1 plug transplants (PSB 211 + 1) and 1+1 bare root transplants - is preferable for outplanting amabilis fir in two high elevation biogeoclimatic subzones of the Vancouver Forest Region; namely, the Wetter Maritime Coastal Western Hemlock Subzone (CWHb) and the Maritime Forested Mountain Hemlock Subzone (MHa). Results are drawn from the fall 1978 - spring 1979 outplantings where data covering field performance for the first two growing seasons are now available.

In the MHa Forested Subzone, there were no significant differences in seedling survival for all three stock types. Although spring planting gave significantly higher (p=.01) survival rates, fall-spring differences in this subzone never exceeded 9%. Forest managers, faced with an operational decision as to when to plant in this subzone, with its extremely restricted planting season in both fall and spring, would be well advised to carefully consider these comparative data.

In the CWHb, fall planted 1+1 bare root stock gave significantly lower survival than plug or plug transplant stock. Spring planting in this subzone yielded no significant survival differences between stock types but it did yield significantly higher (p=.01) survival rates than fall planting.

Both bare root and plug transplants displayed planting shock in the first growing season in marked contrast to the plug seedlings, which doubled their height in the same period. In fact, 1+0 plug seedlings were taller than 1+1 bare root stock in the first year after planting in both biogeoclimatic subzones.

In conclusion, these data indicated that stock type had little significant effect on survival of amabilis fir seedlings two years after planting in high elevation subzones of the Vancouver Forest Region. However, 1+0 plug stock provided the best growth rates, and 1+0 plug transplant stock the greatest overall size, of the three stock types being evaluated in these trials.

### DEVELOPMENT OF REFORESTATION METHODS FOR AVALANCHE CONTROL (E.P. 781.01)

C.F. THOMPSON

A small test plantation of subalpine fir established in 1978 continues to grow slowly. Annual average growth is 1.2 cm. Survival continues to fall, with the majority of the mortality in the plot on the better site with the heavy growth of bear grass (Xerophyllum tenax). The vegetation is acting as shelter for small rodents which are clipping the seedlings at or just above the root collar.

There were only a few cones of alpine larch, the majority of which were destroyed by frost. Whitebark pine had a modest cone crop, and two small collections were made. One collection was made in mid-October after protecting the cones with chicken netting screens and the second collection was made by cutting off cone-bearing branches and keeping the branches in water until mid-October. Both techniques permitted the cones to develop without bird predation. The seed development in both collections was considerably better than in any collection to date, but was less than expected due to the retardation of growth by the cooler than normal growing season.

## OPERATIONAL PLANTING TRIALS (E.P. 790.01) M.B. CLARK

Three operational planting trials for lodgepole pine were initiated in the Kamloops Forest Region in 1980. The objective was to compare the survival and growth of different stock classes of the same seedlot on different sites in production plantations. In 1981, data were collected on survival, growth and condition of seedlings within each trial.

Two additional trials were established to compare: (a) fall and spring planting of two stock classes of one species (SX 81104K) and (b) different species and stock classes on one site (SX 81105K). First year survival, growth and condition assessments were made at the end of the 1981 growing season.

Only in trial SX 81105K was there any significant difference in survival between stock classes. The lodgepole pine bareroot stock showed much poorer survival than other species and stock classes. In trial SX 8010K the mudpacked stock produced significantly less height growth than other stock classes during the first 2 years. In trial SX 81105K the container stock of pines along with 1 1/2 + 1/2 bareroot stock of Douglas fir produced the best height growth during the first growing season.

Seedlings within a number of the trials have been severely damaged by animals and have reduced height growth due to 'winter kill' of leaders. The deer damage to seedlings within SX 80102K has eliminated the usefulness of this trial for further growth assessments.

## REGENERATION PERFORMANCE ASSESSMENT (E.P. 790.02) M.B. CLARK

The purpose of this study is to collect information on regeneration growth performance and to facilitate development of acceptable species and stock growth standards for biogeoclimatic subzones and associations. The performance of operational plantations and natural regeneration may then be evaluated with respect to these standards.

Over the past two years the emphasis on data collection has been with plantations. Data were collected on 270 selected plantations. An additional 103 plantations were examined but were rejected because of unacceptable survival or damage (browsing, frost) which inhibited growth for more than one year.

Standards have been plotted. Additional sampling will be necessary to cover gaps in the present data base.

### PLANTATION PERFORMANCE ASSESSMENT IN THE NELSON FOREST REGION (E.P. 802)
C.F. THOMPSON

This project was reduced in scale from previous years. Selected plantations from the past 2 or 3 years were monitored for performance in terms of height growth and survival. Specific concerns resulting from this project include the quality of planting stock after long-term storage, particularly in facilities used for apple storage; the apparent inability of roots to develop adequately on plug seedlings in fine-textured soils; and the absence of plantation growth standards.

Work was initiated on the development of plantation growth standards for the region. A total of 95 plantations were examined in 5 biogeoclimatic subzones. Of these plantations, 65 were spruce, 17 lodgepole pine and 13 Douglas fir, represented by 5 stock types and 5 site preparation techniques. Preliminary standards have been derived, but these require verification and additional data before they can be made available for operational use. This will be addressed in the upcoming year.

### THE EFFECT OF FELLER-BUNCHER/GRAPPLE-SKIDDER LOGGING ON LODGEPOLE PINE CONE DISTRIBUTION AND REGENERATION (E.P. 820) M.B. CLARK

The objective of this study is to monitor the effectiveness of natural lodgepole pine regeneration after feller-buncher/grapple-skidder logging. Plots were established on 14 sites in 1978, and on an additional 2 sites in 1979, to examine seedbed distribution and density of natural regeneration after harvesting and site preparation. By 1981, regeneration on 9 of the 16 areas was sufficient to at least satisfy minimum satisfactory stocking levels. So far, the findings suggest that amount and distribution of regeneration is more closely related to acceptable levels of quality cone distribution than to quality and quantity of seedbed disturbance.

### GROWTH AND FERTILIZER RESPONSE OF CONTAINER-GROWN AND BARE ROOT INTERIOR SPRUCE STOCK (E.P. 858) A.N. BURDETT, L.J. HERRING AND C.F. THOMPSON

Large 300 $cm^3$ 1+0 PSB 615 spruce plugs outgrew standard 2+0 bare root stock in each of three trials; one in the Nelson Forest Region, two in the

Prince George Forest Region. During the first season, height growth of the plugs was more than twice that of the bare root trees. Fertilization at planting with a slow release NPK fertilizer increased first season height growth of the plugs by 20 to 30%. The bare root trees showed no fertilizer response in the first year.

Second year performance data have been obtained from one plot. They show a continuation of the superior performance of the plug stock although relative growth in both height and stem volume was less in the second year than the first. In both stock types the magnitude of the second year fall down in growth was reduced by fertilization at planting. The effect of fertilization on height growth was due to an increase in the number and length of stem units (distance between adjacent needles).

At the end of the second growing season, the fertilized plugs had twice the stem volume of the unfertilized plugs. They had 10 times the stem volume of the fertilized bare root trees.

Several seedlings infected with the shoot tip fungus Sirococcus strobilinus Preuss were observed in the Prince George plantations (see Plate 4).

## FIELD PERFORMANCE OF SMALL VOLUME CONTAINER SEEDLINGS (E.P. 859.07) A. VYSE

Operational plantations of spruce, lodgepole pine and Douglas fir in the central interior of British Columbia were examined to compare field performance of small volume container seedlings and bare root seedlings and transplants. The performance of spruce container seedlings was judged superior to bare root seedlings and transplants. Lodgepole pine container seedlings survived and grew as well as bare root seedlings. The performance of a limited number of Douglas fir plantations was less than satisfactory for both stock types.

## LARGE PLANTING STOCK FOR COASTAL ALLUVIAL SITES (E.P. 885.04) J. POLLACK

The objective of this project is to determine the length of time required for various sizes of Sitka spruce planting stock to reach "free growing" status on coastal alluvial brush sites. The project was established in April, 1981 at Hirsch Creek near Kitimat. Four Sitka spruce stock types, ranging from PSB 211 to PSB 615 1+0, were planted on a winter-logged alluvial spruce site dominated by dense herbaceous vegetation. A randomized complete block design utilized the four stock types and two brush treatments - control and manual cleaning each July - with three replications. Each plot consisted of 50 seedlings with a total project size of 1 200 seedlings. The first and second growing season evaluation of the project will be available in late 1982.

Plate 4. White spruce seedling with tip wilt due to infection by Sirococcus strobilinus. The seedling was spring planted and photographed in October of the same year. Infection probably occurred in the field rather than in the nursery, since infected natural spruce regeneration were observed when the seed was planted.

## ECOPHYSIOLOGICAL BASIS FOR GROWTH REPRESSION IN LODGEPOLE PINE (E.P. 893.01)

J.H. BASSMAN

A study of 3 years duration was initiated in the Cariboo Forest Region to elucidate the physiological and environmental determinants of growth repression in young stands of lodgepole pine. The objective is to obtain a thorough knowledge of the salient attributes of growth repression, leading to more scientifically based cultural prescriptions. The four major physiological determinants of growth and yield are being investigated: (a) rates of photosynthesis and respiration; (b) development of photosynthesizing leaf area; (c) partitioning of dry matter within the tree, and (d) efficiency of nutrient and water use. Five density classes provide comparisons between unrepressed stands (5 000, 20 000 stems/ha), stands just at or approaching repression (50 000 stems/ha), and repressed stands (100 000, 150 000 stems/ha). Three levels of fertilizer (0, 100, and 200 kg N/ha) test the effects of increased nitrogen.

Seasonal patterns of transpiration, leaf resistance, xylem sap potential and soil moisture were determined through periodic measurements over the entire summer. Intensive, diurnal measurements of photosynthesis, light and temperature profiles, and water relations were conducted in August. For both seasonal and diurnal samplings, two needle age classes and two crown positions were evaluated for each tree measured.

First year biomass harvesting was conducted during October to establish plant resource allocation patterns and diameter-height-crown relations. The most intensive sampling scheme involved complete partitioning of 1-5 trees in each of the 5 density classes into 1, 2 and 3 year and older components. These were further partitioned into needle, branch and main stem samples. Leaf area, leaf area index, $D^2H$ functions, and other growth analysis functions are being estimated from these data.

## EFFECT OF MOUNDING AND SCARIFICATION ON GROWTH AND WATER RELATIONS OF PLANTED SPRUCE SEEDLINGS (E.P. 893.02) J.H. BASSMAN AND M. ROYDHOUSE.

A preliminary study was carried out to evaluate the effects of mounding and scarification on growth and water relations and some other physiological processes in planted white spruce seedlings. Swedish research has demonstrated increased survival and early growth of spruce and pine planted in scarified patches and mineral soil mounds. These improvements are apparently the result of increased soil temperatures and a concomitant increase in root growth. It is not known whether similar gains can be achieved on high elevation sites in the Cariboo. Both mounding and scarification could have physiological trade-offs that might negate gains in improved soil temperatures.

Interior spruce 1+0 PSB 211 seedlings were planted in mid-June in an unburned cutblock at 1 550 m elevation near Spanish Lake, Cariboo Forest Region. Treatments were (a) control (planted through LFH layer, no site preparation); (b) planting on the north side of a scarified patch, near humus material; and (c) planting on a mineral soil mound 30 cm in diameter and 15 cm deep. Soil temperatures, xylem sap potential, transpiration rates and biomass allocation were determined at intervals throughout the summer.

Soil temperature in the mound was consistently higher than either the scarified patch or the control (Table 8). Root growth in the mound was also substantially greater than on the control or scarified patch. By September 7, mound plants had 176% and scarified patches 133% of the root biomass in controls. Above ground growth was greater in both scarified patches and mounds than for controls, however, trees growing in scarified patches showed higher above ground biomass than those in mounds in late August. Both mounding and scarification resulted in a deterioration of plant water relations. Transpiration rates were reduced and stomatal resistance increased in both treatments, the mound being most adversely affected. More intensive investigations into the environmental and physiological effects of site preparation are planned for 1982.

Table 8. Seasonal soil temperatures at 5 cm and 10 cm below the surface in control, scarified patch and mounding treatments.

| DATE | SOIL TEMPERATURE C° | | | | | |
|---|---|---|---|---|---|---|
| | 5 cm | | | 10 cm | | |
| | Control | Scarified | Mound | Control | Scarified | Mound |
| June 30 | 9.7 | 9.5 | 11.3 | 8.2 | 8.8 | 10.0 |
| July 23 | 13.3 | 14.7 | 16.3 | 11.3 | 10.7 | 15.3 |
| August 19 | 17.7 | 17.7 | 25.3 | 14.3 | 14.7 | 19.3 |

## PLANTATION GROWTH PERFORMANCE ANALYSIS IN THE NORTHERN INTERIOR (E.P. 938)

D.A. DRAPER AND S. WALSH

Plantation growth performance information, normally in the form of height-over-age data, has been collected by a number of individuals in the Prince George Forest Region as a result of concern over early growth rates of interior species (see also E.P. 859). Lack of uniformity in sampling techniques and method of measurement limit the use of these data. Similarly the statistical reliability and potential of such data remains untested. E.P. 938 examines plantation height performance data identified by stock type, year of planting, site preparation and planting season. Work in 1981/82 involved initial data organization, coding and computerization.

## IMPROVED TREE HEIGHT MEASURING POLES D.K. GARTHWAITE

Continued development of Research Branch height-measuring poles has resulted in further refinements to increase the efficiency of the telescoping design. Graduations are now marked on each section such that any extended height is read directly at the base. To avoid confusion as to which direction the sections were turned for locking during extension, a control pin has been added which restricts the locking and release of all sections to a single pattern.

Interest is increasing in these height poles, with inquiries received from the Canadian Forestry Service, United States Forest Service in West Virginia and California, University of Nebraska, and the B.C. forest industry. Eight 8 m poles are currently on order for the Pacific Forest Research Centre and the Ministry of Forests.

With increasing bulk orders the suppliers of the aluminum tubing are able to guarantee true sliding fits for all the sections. Present recommendations are that the telescoping friction-plug pole is best suited for height measurements under 12 m, and the stacking slot-pin pole above 12 m.

## SLOW RELEASE FERTILIZATION OF DOUGLAS FIR AT PLANTING (E.P. 946.02) R. VAN DEN DRIESSCHE

Fertilization at planting appears to be an operational practice in establishing plantations in some areas of the world, particularly New Zealand, Australia and South Africa. In these countries quite large amounts of nutrient, for example 17 g elemental P or 15 g elemental N, are applied per tree. The fertilizer is commonly inserted in a hole about 15 cm from the tree, but may also be broadcast. The type of fertilizer, method of placement and seedling growth rate interact, and it seemed that slow releasing fertilizers might be more appropriate for initial experiments since placement would probably be less critical.

An experiment was established in March, 1981 with 2+0 Douglas fir on a sandy loam, containing 0.04% N, near Campbell River airport. Agriform (20-10-5) and Osmocote (17-7-12) fertilizer were applied to supply 5 levels, 0.0, 4.2, 8.4, 16.8, and 33.6 g N per tree. Two placement methods were also tested: (1) broadcast in a ring about 15 cm from the tree (2) placed in holes 15 cm from the tree.

During the first season after planting new shoot growth was increased by addition of fertilizer up to 33.6 g N per tree. Unfertilized trees grew 9.4 cm and trees receiving 33.6 g N grew 12.3 cm. Broadcast application also increased growth significantly more than placement in a hole 15 cm distant from the tree. Unfertilized trees looked chlorotic, but heavily fertilized trees looked dark green and had larger needles. The apparently better nutrient status of heavily fertilized trees may mean greater growth differences will develop between different treatments in following years.

## FERTILIZATION OF INTERIOR SPRUCE AT PLANTING IN THE CARIBOO FOREST REGION (E.P. 859.04) R. VAN DEN DRIESSCHE AND A. VYSE

An experiment to see whether fertilization at planting can offset planting check of spruce is in progress in the Spanish Lake area of the Cariboo Forest Region. Three different slow release fertilizers, sulphur coated urea (36.2-0-0-16.8S), Agriform (21-10-5) and Osmocote (17-7-12) have been applied to provide 0.0, 4.2 and 8.4 g N per tree. Three methods of fertilizer placement were also incorporated in the design, namely (1) placement in the planting hole, (2) placement in a hole 15 cm from the tree and (3) broadcast around the tree. Two-year old bare root interior spruce were planted for this experiment in May, 1980.

Survival has remained essentially unchanged from the first year, when it was found that placement in the planting hole caused mortality. Average new shoot growth of untreated seedlings was 6.2 cm during 1981. The best treatment, which was Osmocote broadcast at 8.4 g N per tree, resulted in new shoot growth of 10.6 cm. Thus there is some promise that fertilizer can be used to improve early growth of bare root 2+0 interior spruce as currently produced from the nurseries. Osmocote was significantly better than either sulphur coated urea or Agriform for stimulating new growth and broadcasting was better than placement in a hole 15 cm from the tree.

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## ACTIVE EXPERIMENTAL PROJECTS

| | | |
|---|---|---|
| E.P. 368 | Adaptability of tree species to sites | K.F. Bradley |
| E.P. 590 | Compatibility of tree and grass seeding in the Kamloops Forest Region | M.B. Clark |
| E.P. 618 | Cone crop periodicity in spruce, Nelson Forest Region | C.F. Thompson |
| E.P. 712 | Tree species trial in the Kitimat Valley | J. Pollack |
| E.P. 741 | Biological effectiveness of equipment tested in silvicultural mechanical site preparation | R. McMinn,<br>L.J. Herring |
| E.P. 759 | High elevation species and stock type trials | J.T. Arnott (CFS)<br>F.T. Pendl |
| E.P. 766 | Planting hazard index studies | F.T. Pendl |
| E.P. 781 | Development of reforestation methods for avalanche control | C.F. Thompson,<br>F.T. Pendl |
| E.P. 790 | Determination of the causes of mortality in young plantations | M.B. Clark |
| E.P. 800 | Drag scarification | L.J. Herring |
| E.P. 802 | Plantation performance assessment in the Nelson Forest Region | C.F. Thompson |
| E.P. 804 | Lodgepole pine natural regeneration | J. Pollack |

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| E.P. 805 | Study of logging methods aimed at protecting subalpine fir natural regeneration | J. Pollack |
| E.P. 814 | Tree species trial on the Queen Charlotte Islands | J. Pollack |
| E.P. 820 | The effect of feller-buncher/grapple-skidder logging on lodgepole pine cone distribution and regeneration | M.B. Clark<br>A. Vyse |
| E.P. 829 | Exploratory study of logging and ATV damage in dry belt Douglas fir | M.B. Clark |
| E.P. 841 | The effect of canopy removal by diameter limit cutting on plant moisture stress and foliage condition in advanced regeneration of Douglas fir | A. Vyse |
| E.P. 847 | High elevation regeneration problems in the coastal western hemlock zone | J. Pollack |
| E.P. 858 | An evaluation of new methods for the production of forest planting stock | A.N. Burdett |
| E.P. 859 | The early growth of interior spruce plantations in the Cariboo Forest Region | R. van den Driessche<br>A. Vyse |
| E.P. 885 | Large planting stock for conifer release on coastal alluvial sites | J. Pollack |
| E.P. 893 | Ecophysiological studies of regeneration problems in the interior of B.C. | J. Bassman |
| E.P. 898 | Management interpretations for the hemlock - true fir variant of the Interior Cedar - Hemlock Zone | J. Pollack |
| E.P. 904 | White pine in the Cariboo Forest Region | A. Vyse |
| E.P. 933 | Planting site and stock treatments for brushfield conversion | L. Herring |
| E.P. 938 | Plantation growth performance analysis in the northern interior | D.A. Draper<br>S. Walsh |

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| E.P. 945 | Determination of the quantity of mineral soil exposure for satisfactory establishment of domestic grasses on clearcuts | M.B. Clark |

# STAND DENSITY CONTROL AND FERTILIZER APPLICATION

Manipulating stand density and applying fertilizers can enhance tree growth and improve merchantable yields, but insufficient data are available to determine which sites and stands produce best responses. Such information is essential for planning silviculture programs and deciding treatment priorities.

In coastal areas, analysis of 6 year growth data was conducted for the Forest Productivity installations, and routine remeasurements were carried out for several spacing and thinning studies. For interior regions, emphasis was placed on intensive silviculture of lodgepole pine: work commenced on extensive empirical trials designed to test fertilizer responses, and a working plan was prepared for espacement and juvenile spacing.

## SPACING TRIALS OF LODGEPOLE PINE (E.P. 671) J. POLLACK

Four densities (747 to 2 990 stems/ha) of lodgepole pine were examined five and ten growing seasons after planting. No significant differences in mean dbh, basal area and height were noted among plots at 5 years. At 10 years there were significant differences among plots in average dbh, basal area and periodic (1973-78) annual diameter and basal area increments with no significant differences in either height or periodic annual height increment.

Mean diameter ranged from 4.85 cm at 747 stems/ha to 4.07 cm at 2 990 stems/ha whereas, corresponding basal areas were 20.08 $cm^2$ and 13.94 $cm^2$, respectively. No significant changes in individual tree diameter or basal area occurred for the first 10 years when the planting density increased from current operational standards (1 600 stems/ha) to 2 990 stems/ha or decreased to 747 stems/ha. However, trends in the periodic annual increments indicate that more rapid growth will accrue to crop trees at lower densities; these potential increases may be visible at the 15 year assessment.

The study indicates that silviculturists have a wide choice of stocking levels for lodgepole pine in the first 10 years of plantation growth. Planting densities of 1 800 stems/ha will not reduce increment to crop trees, and will allow for moderate levels of mortality and permit juvenile spacing at 15 to 20 years.

## FERTILIZER RELATED DENSITY CONTROL OF LODGEPOLE PINE (E.P. 789.03) L. HERRING

The objective of the study is to test the effectiveness of toxic application levels of urea fertilizer for reducing the density (300 000 stems/ha) of 18-year old, repressed lodgepole pine. After one year the effects of urea toxicity do not appear to justify this method of spacing. The urea-related mortality at the highest fertilizer concentration (800 kg N/ha applied in narrow bands spaced 2 m apart throughout the stand) accounted for a reduction of only 26% of the total stand density. An unexpected, yet far more significant density reduction of 53% occurred as a result of topping and browsing by snowshoe hares (Lepus americanus), which exhibited a feeding preference for lodgepole pine saplings with increased stem and foliage nitrogen content. While hare and urea related mortality is likely to continue at a much lower level for several more years, the combined impact for the peak year (89% density reduction) is still far from that required to consider this an effective and realistic means of treatment.

## HERBICIDAL DENSITY CONTROL OF LODGEPOLE PINE STANDS (E.P. 789.05) L. HERRING

Another chemical approach to spacing overly-dense lodgepole pine is through the application of soil-active herbicides. An experiment was established in 1979 to test the effectiveness of Tordon 10K pellets and liquid herbicide (active ingredient picloram), Velpar "Gridball" pellets (active ingredient hexazinone) and Hyvar XL (active ingredient bromacil) in an 18-year old stand carrying approximately 100 000 stems/ha with dominant tree heights of 3 m. Herbicides were applied in two distributions; in grid spot intensities of 3x2, 2x2 and 2x1 m, and in narrow strips spaced 2 m apart. By varying grid intensities, spot volumes and liquid solution rates, 22 treatment combinations were applied in the study.

Velpar, applied in any spatial distribution and up to 3.9 kg a.i./ha was ineffective in killing lodgepole pine. This apparent tolerance may prove to be a useful characteristic when Velpar is used as a conifer release agent. Of the two picloram herbicides, the pelletized, Tordon 10K resulted in the greatest reduction (86%) in stand density, when applied at 7.5 kg a.i./ha in strips. Tordon Liquid Ester was only half as effective (40%) in reducing stand density when used at 6.65 kg a.i./ha in a strip application. Both Tordon products produced serious sublethal symptoms in the surviving stand. Up to 90% of the living trees remaining in the stand are displaying severely abnormal shoot growth and poor overall vigor. This symptom is undesireable from the standpoint of juvenile spacing since these sublethally affected trees still contribute competitive stress to healthy survivors.

Hyvar XL proved to be potentially useful in chemical spacing. When applied in strips at 3.99 kg a.i./ha it reduced stand density by 76%. Spot applications of 9.58 kg a.i./ha gave density reductions of 87%. When applied at rates higher than 10.00 kg a.i./ha total stand mortality resulted. An important characteristic of Hyvar treatments is its "clean kill" effect; less than 5% of survivors exhibit sublethal toxicity symptoms. There was also no apparent shift in stand and tree size characteristics after Hyvar treatments, indicating no selectivity in herbicide effect.

For all treatments, there was no apparent relationship between herbicide placement and the spatial pattern of tree mortality. Herbicide uptake and subsequent tree mortality is likely a function of random root distribution; strip thinning with a soil-active chemical may only be possible in much younger stands with a more compact root system. Further experiments with Hyvar XL were established during 1981. E.P. 789.05 will continue to be monitored to determine tree and stand responses to chemical density reductions.

## TREE INJECTOR SYSTEM DEVELOPMENT AND TESTING (E.P. 867) B. DILLISTONE

The basic system, project objectives and methods and the results of dosage trials after one growing season, have been summarized previously (Forest Research Review 1980/81). Dosage trials in western hemlock and Douglas fir on Vancouver Island have now been assessed, and the findings follow the predicted pattern: defoliation continues over the second growing season; all seasonal treatments are effective; no "flashback" has been observed. Dosage regimes for spacing these species may now be adjusted: one capsule for 8 to 10 cm diameter trees; two capsules for 10 to 12 cm diameter trees; three capsules for 12 to 14 cm diameter trees. These are vertical placements on one side of the tree. No data are available yet for the lodgepole pine spacing trials in the interior.

## FATE OF NITROGENOUS FERTILIZERS APPLIED TO SNOW (E.P. 870) V.G. MARSHALL/ P.R. BARKER

Chemical analysis continues for soil, water, snow, and plant material collected from the initial experiment established near Spillimacheen; an automatic data logger was also installed to monitor meteorological conditions. A report outlining preliminary results was submitted during 1981.

On Vancouver Island, two trials commenced in 10-year old stands of Douglas fir. Hydrological studies were emphasized at Green Mountain, where movement of water and nutrients was measured on an area 20 x 60 m, after applying urea on a 57 cm depth of snow. Two single-tree plots were fertilized with $N^{15}$ urea, and growth data will be obtained from three fixed-area plots; an automatic data logger was also installed. Four plots were established on another site near Sooke, and treated with urea after receiving 50 cm of snow.

Urease activity was determined for a Luvisol and a Brunisol in the Prince George Forest Region, and for a Podzol in the Vancouver Forest Region.

## FERTILIZER SCREENING TRIALS IN THE INTERIOR OF B.C. (E.P. 884) G.F. WEETMAN AND R. FOURNIER

Results from 17 experiments with lodgepole pine suggest nitrogen deficiency occurs commonly, but additional phosphorus and potassium are infrequently required to enhance tree growth. Operational use of nitrogen fertilizer is not recommended until sufficient quantitative studies determine the magnitude of response, and identify optimum rates of treatment.

Data from seven trials with interior Douglas fir and one with white spruce imply that benefits of fertilizing are small and uncertain, and that further research is needed encompassing more sites. Experiments involving larch and sub-alpine fir are also recommended.

## FERTILIZING AND THINNING IN INTERIOR FORESTS (E.P. 886.01) P.R. BARKER

The background details for this experiment are outlined in Forest Research Review 1980/81:46. During 1981, the first two installations were established near Lac Le Jeune, in the Kamloops Forest Region. Both sites are located in the Very Dry Southern Montane Spruce (MSc) Subzone, and support 18-year old stands of lodgepole pine. For each experiment, nine circular plots of 0.05 ha were used, surrounded by concentric buffer zones of similar area. This design accommodated three replications of each treatment, viz control, 100 kg N/ha, and 200 kg N/ha; urea fertilizer was applied at prescribed rates during October. One stand had been operationally spaced to 1 100 stems/ha in 1978, and all plots on the other site were thinned to a comparable density immediately after fertilizing. Besides plot establishment, extensive reconnaissance was undertaken throughout interior regions, to identify areas for further study during 1982.

## INTRODUCING NITROGEN INTO A YOUNG PL STAND: A COMPARISON OF METHODS (E.P. 886.02) D.A. DRAPER

Early growth of conifers in the interior of B.C. may be limited by available nutrients. This experiment is designed to compare measured individual tree and stand response of 7-year old lodgepole pine to the addition of nitrogen. Three nitrogen-fixing species (Lupinus perennis, Alnus viridis, Trifolium hybridum) were established as separate treatments beneath the young pine. In addition forest grade urea (46-0-0) was applied at a rate of 200 kg/ha. A control completed the five treatments tested. In 1981/82 the working plans were prepared, the experiment located in the field and treatments applied. Lupine survival was poor despite hand scarification and the protection of the partial pine canopy. Alder survival was excellent using plug (PSB 415) stock grown from local seed at Red Rock Nursery.

## RESPONSE OF LOW-MERCHANTABILITY, REPRESSED LODGEPOLE PINE TREES TO SPACING AND FERTILIZATION (E.P. 886.03) D.A. DRAPER

Over-dense, low merchantability pine stands 30-75 years of age are common throughout the interior of B.C. Improving yield in these stands represents a short-term strategy to meet anticipated TSA timber short falls. This experiment uses paired tree techniques to evaluate response to treatments including fertilization, spacing and their combination. Treatment selection and treatment level is regionally specified. In 1981 a case study installation was located in the Prince George Forest Region to examine the influence of spacing plus fertilization (urea 46-0-0 at 150 kg/ha) in a 53-year old stand of lodgepole pine originally at 4 600 stems/ha. The stand was selectively spaced to 1 035 stems/ha.

## FOLIAR ANALYSIS RESEARCH (E.P. 889) T.M. BALLARD

Nitrogen, sulfur, iron, phosphorus, boron, and potassium deficiencies were diagnosed from foliar analysis for the Prince George, Cariboo, and Kamloops Forest Regions. Of these deficiencies, the last three appear least common and least serious. Nitrogen deficiencies are most common and nearly always most serious. Zinc appears to be seriously deficient in hemlock and somewhat deficient in some western red cedar and Douglas fir in the Valemont-McBride area, where lodgepole pine and spruce indicate no zinc deficiency. Unusually low boron levels, almost certainly indicating deficiency, are found on some sites in the area. Studies were carried out to improve foliar sampling procedures and methods for total iron and copper analysis. Computer programs were developed or modified to make foliar analysis data files and diagnose nutrient status of spruce, Douglas fir, western hemlock, western red cedar, and lodgepole pine.

## AN INVESTIGATION OF TOPOPHYSIS IN THE REPRESSION OF LODGEPOLE PINE (E.P. 932) D.A. DRAPER AND J. WORRALL

The response of repressed lodgepole pine is hypothesized as, in part, a function of meristematic suppression which may be likened to observed topophysis effects. A series of controlled grafting experiments were carried out to evaluate the importance of the apical meristem in influencing height growth response to treatment. Two categories of rootstock were identified upon the basis of the previous year leader extension: a) vigorous rootstock (greater than or equal to 200 mm extension) and b) repressed rootstock (less than 200 mm extension). The same criteria were used in selecting apical leader scion material. All rootstock and scion material was of the same age. In each rootstock category three treatments were considered a) grafting with repressed scion material, b) grafting with vigorous scion material and c) control tree - no grafting. Apical extension will be measured and compared to identify effects of scion, rootstock and grafting.

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## ACTIVE EXPERIMENTAL PROJECTS

| | | |
|---|---|---|
| E.P. 62, 63<br>64, 66 | Thinning methods and intensity | K.F. Bradley |
| E.P. 204, 205 | Thinning and pruning | K.F. Bradley |
| E.P. 283 | Thinning control | K.F. Bradley |
| E.P. 364, 365 | Thinning intensity | K.F. Bradley |
| E.P. 370 | Partial cutting in the Columbia Forest Zone | C.F. Thompson |
| E.P. 384, 385 | Thinning experiments in lodgepole pine, Canal Flats | C.F. Thompson |
| E.P. 388 | Commercial thinnings in western hemlock, East Thurlow Island | K.F Bradley |
| E.P. 418 | Thinning experiment in juvenile Douglas fir, Cowichan Lake | K.F. Bradley |
| E.P. 429 | Spacing trials of pure and mixed stands | K.F. Bradley |
| E.P. 469 | Thinning experiment in juvenile Douglas fir, Elk Falls | K.F. Bradley |
| E.P. 511 | Crop-tree thinning of western larch Perry Creek, East Kootenay | C.F. Thompson |
| E.P. 517 | Experimental thinning and pruning of Ponderosa pine | M.B. Clark |

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| E.P. 534 | Spacing trial of Douglas fir, 16 Creek Vancouver Island | K.F. Bradley |
| E.P. 537 | Spacing trial of white spruce, Topley Landing | J. Pollack |
| E.P. 549 | Spacing trials in the Prince George Forest Region | L.J. Herring |
| E.P. 554 | Thinning of Douglas fir, Sayward Forest | K.F. Bradley |
| E.P. 570 | Sitka spruce spacing trials | J. Pollack |
| E.P. 571 | Trials in tree species and spacing on west coast of Vancouver Island | K.F. Bradley |
| E.P. 607 | Spacing trial of Ponderosa pine, Falkland, Kettle Valley and Cherry Creek | M.B. Clark<br>C.F. Thompson |
| E.P. 630 | Effects of circular spacing on individual trees in overstocked juvenile stands of lodgepole pine, Sheraton | J. Pollack |
| E.P. 660 | Species and spacing trials in the Montane Forest Section | L.J. Herring |
| E.P. 671 | Spacing trials of lodgepole pine | M.B. Clark<br>J. Pollack<br>L.J. Herring |
| E.P. 703 | Responses of immature Douglas fir and western hemlock to thinning and fertilizer application | P.R. Barker,<br>G.A. Godfrey |
| E.P. 789 | Mechanical spacing in lodgepole pine stands | L.J. Herring |
| E.P. 840 | Forest fertilization in the Kamloops Forest Region | T.M. Ballard |
| E.P. 842 | The effects of stand density on the top height of lodgepole pine stands in the Cariboo Forest Region | A. Vyse |
| E.P. 850.02 | Investigation of the causes of stagnation in lodgepole pine stands | K.J. Mitchell |

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| E.P. 853 | Monitoring nutrient uptake following fertilization in the Queen Charlotte Islands | J. Pollack |
| E.P. 867 | Tree Injector System | B. Dillistone |
| E.P. 870 | Fate of nitrogenous fertilizers applied to snow | V. Marshall (CFS) |
| E.P. 884 | Fertilization screening trials in the interior of B.C. | G. Weetman |
| E.P. 886 | Fertilizing forests in the interior of B.C. | P.R. Barker |
| E.P. 889 | Development of foliar analysis techniques to determine forest fertilizer requirements | T.M. Ballard |
| E.P. 922 | The effect of spacing on the growth and yield of lodgepole pine | W. Johnstone |
| E.P. 932 | An investigation of topophysis in the repression of lodgepole pine | D.A. Draper<br>J. Worrall |

## FOREST PROTECTION

Research in this section is aimed at developing methods to reduce damage to commercial forests caused by insects, diseases, weed competition and animals. In 1981/82, research focused on damaging agents affecting lodgepole pine management in the interior. This is a reflection on the increasing importance of lodgepole pine in interior silvicultural programs. Hare and squirrel population monitoring and damage assessments continued in the Prince George and Cariboo Forest Regions. A Research Summary with management strategies for dwarf mistletoe control was prepared for the Cariboo Forest Region. Similar reports are under preparation for other lodgepole pine pests such as the terminal weevil, rusts and cankers. The formation of a new vegetation control research program has been approved, and is currently in the staff recruitment phase. A draft standard working plan for herbicide research trials has been prepared and is currently undergoing technical review.

### THE EFFECTS OF ANIMAL DAMAGE ON SPACING TRIALS IN NATURAL STANDS OF LODGEPOLE PINE (E.P. 845) T.P. SULLIVAN

An investigation of the extent of snowshoe hare and red squirrel damage to spaced (1979) lodgepole pine was continued at the Bowes Creek study area east of Prince George. Feeding attacks to crop trees increased dramatically (74.8% hares; 26.7% squirrels) during the winter of 1980/81 after little damage (2.9% hares; 0.0% squirrels) the previous winter. The total incidence of damage in a control stand was 65.7% by hares and 14.3% by squirrels in 1981. Frequency of girdling was 7% in the spaced and 5% in the control stand. These values reflect outright mortality and although important, do not represent the overall health of the stand in terms of the unknown effect of bark removal on future growth and yield. Population monitoring indicated that hare densities are declining compared with previous years. Squirrel population monitoring began at this study area and in the Cariboo during 1981 for predicting potential outbreaks of damage. A regional assessment of damage in the Cariboo indicated that squirrels were the major problem affecting lodgepole pine juvenile spacing in both the dry and wet belts. Frequency of girdling reached as high as 25% in a spaced stand.

## THE EFFECTS AND CONTROL OF LODGEPOLE PINE DWARF MISTLETOE IN THE CARIBOO FOREST REGION (E.P. 910) E. WILFORD

Lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) is a pervasive pest in the Cariboo Forest Region. This parasitic flowering plant is found throughout the region but is particularly prevalent in the drier areas with extensive pure pine stands. Sampling studies conducted by the Canadian Forestry Service throughout the region have revealed that 72% of pine stands have some degree of infection, and that 85% of stands in the dry Chilcotin area are similarly affected. These striking regional infection levels are higher than any recorded elsewhere in North America.

A report has been prepared to summarize the biological principles of control and the management techniques that can be used to effect control for operational staff. The report emphasizes that the regional dwarf mistletoe control policy should have three components:

1. Give highest priority to control measures that can be integrated with ongoing harvesting and silvicultural procedures e.g. removal of non-merchantable but infected stems at time of harvesting or removal of infected stems during juvenile spacing operations.

2. Compare cost and effectiveness of backlog treatments such as removing scattered infected stems from old cutblocks with other types of intensive forestry projects designed to increase future timber supplies.

3. Support a limited scale research program designed to estimate probable impact of control measures on tree and stand growth.

## ACTIVE EXPERIMENTAL PROJECTS

| | | |
|---|---|---|
| E.P. 839 | Lodgepole pine seed damage by deer mice and related small mammals | T.P. Sullivan |
| E.P. 845 | The effects of animal damage on spacing trials in natural stands of lodgepole pine | T.P. Sullivan |
| E.P. 852 | Test to determine most effective lethal trap technique for spruce beetle control | J. Pollack |
| E.P. 894 | Investigations on the impact of the lodgepole terminal weevil on lodgepole pine in the B.C. interior | T. Maher/J. McLean |
| E.P. 895 | Impact and management of blister rust and Atropellis canker on interior lodgepole pine | B.J. van der Kamp |
| E.P. 910 | The effects and control of lodgepole pine dwarf mistletoe in the Cariboo Forest Region | E. Wilford |
| E.P. 921 | Damage to commercial forests by wildlife in the Vancouver Forest Region | G. Schuerholz |

## TREE IMPROVEMENT

Changes in staff during 1981/82 include the appointment of a horticulturist, Anne Wood to study cultural problems associated with propagation and clone banks at Cowichan Lake Research Station. Of nine professional positions in the section, two, the Senior Tree Breeder and Lodgepole Pine Breeder, are currently vacant.

Dr. C.J.A. Shelbourne, New Zealand Forest Research Institute, completed a six month sabbatical during which he reviewed coastal breeding programs, particularly for Douglas fir, and made valuable contributions to the development of breeding strategies for other species. Other visiting scientists included Dr. Arno Bruni, University of Vicosa, Brazil, whose mission was to evaluate the potential of the electrophoretic approach for estimating mating systems in the eucalypts. Subsequently, Dr. Francis Yeh began a four month educational leave at the University of Alberta.

Tree improvement and associated research programs continued to grow during 1981, largely in response to needs identified by recently formed tree improvement cooperatives. The past year saw the first formal meetings of the Interior Tree Improvement Council (I.T.I.C.) and its technical planning committees, just two years after the founding of the Coast Tree Improvement Council (C.T.I.C.). Both have demanded considerable time commitments from staff of the section and have necessitated rigorous review and adjustment of breeding strategies and priorities of existing and planned programs. These revisions, which were the major feature of 1981/82 activities, were conducted by Ministry geneticists in collaboration with academic and private sector expertise from Breeding Strategy Sub-committees of both cooperatives.

### SERVICES

In addition to tree breeding and associated research, the Tree Improvement Section has a considerable service role which includes:

1. Operating and maintaining multi-disciplinary research facilities at Red Rock, Kalamalka and Cowichan Lake Research Stations;

2. Operation of a propagation center at Cowichan Lake to serve the requirements of the C.T.I.C. breeding and seed orchard programs. During 1981/82, 843 clones of various conifers were propagated as 28 000 grafts and 21 000 rooted cuttings. In addition, 34 000 yellow cedar cuttings were rooted for reforestation. Propagation on a modest scale was also continued in association with interior tree breeding programs at Red Rock and Kalamalka;

3. Production at Cowichan Lake and Red Rock of container and bare root plants for root-stocks and progeny tests as well as for physiological and silvicultural studies;

4. Continued development of land for, and establishment of clones in gene archives at Cowichan and at Barnes Creek, 60 km northeast of Vernon, to serve the needs of breeders and the interior and coastal cooperatives;

5. Participation by staff in all technical aspects of the cooperative programs, including participation in planning committees, training workshops and seed orchard management committees;

6. Public education and tours at research stations.

## VARIATION STUDIES

The major field undertaking was the establishment of 11 noble fir provenance trials in the coastal region. Height was measured in two Douglas fir (6th year), three lodgepole pine (10th year), six interior spruce (15th year) and two amabilis fir (1st year) tests. Flower production was assessed over 43 lodgepole pine tests, and close monitoring of stem rust infection levels was continued at the Red Rock provenance/family plantation (E.P. 699.04).

Good maintenance (including brushing, removal of wildlings, pruning and tagging) is essential to ensure data of good quality and reliability. During 1981 maintenance was continued at 79 test sites (approximately 110 ha).

### INTERIOR SPRUCES (E.P. 646, 672) B. JAQUISH

Interior spruce (Engelmann, white) provenance tests, established in the Prince Rupert and Prince George Forest Regions between 1965 and 1969,* are yielding valuable information to guide planning in the cooperative tree improvement program. All the test plantations are now between 10 and 15 years old, and increased confidence can be placed in the information obtained from them.

Since the project was last reported (Forest Research Review 1972/73:20), three test plantations (Valemount, Tabor Mountain High and Low) have been terminated due to site-related poor growth and survival. The present conclusions are based on evaluation of as many as 39 provenances at six well-distributed test locations.

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*See Forest Research Reviews 1965-1972 for detailed descriptions of experiments and early results.

High correlations were obtained between provenance mean height rankings at ages 3 and 15. This relatively consistent performance among provenances at different ages is encouraging and indicates that early data may be used to predict future performance in interior spruce plantations.

In general, the results suggest that interior spruces are much more adaptable than previously thought. After 15 growing seasons there is little evidence to suggest that local provenances are ecologically better adapted to local environments than non-local sources, and it appears that substantial relatively low-risk gains in height growth may be achieved by utilizing, on a broader scale throughout the central interior, seed from the Wet Belt transition zone. A more detailed report is being prepared for publication.

LODGEPOLE PINE (E.P. 657) C.C. YING

Data interpretation and its practical application are becoming increasingly important as trials mature. In 1981, lodgepole pine received high priority because of the urgent need to develop a breeding strategy for this species. Highlights of these evaluations include:

1. In terms of height growth, lodgepole pine provenances may be divided into two broad geographic groups (Fig. 3). Those to the left of the line (coast, coast-interior transition, Yukon, and below latitude 49$^{o}$ approximately) were susceptible to winter injury and/or were slow- growing. Seeds from these provenances are unsuitable for use in the interior of B.C.

2. Site has a predominant affect on the growth of lodgepole pine. Mean height after six growing seasons varied from 244 cm at the best site to only 40 cm at the least productive one. Excluding the most northerly sites near Liard River, moisture regime and elevation appear to be the primary factors affecting growth. Trees on dry or high-elevation sites (above 1 610 m) generally grew less than 1 m in 6 years.

3. Provenance x site interaction accounted for only 4% of the total variation in an analysis of variance of sixth year height of the 10 standard provenances (Table 9). Similar results were apparent in analyses involving all provenances by individual regions, indicating that lodgepole pine populations tend to behave consistently, within broad zones, regardless of site. The implication, in terms of practical silviculture and tree improvement, is that the present zonation guiding seed transfer and seed orchard development may be too restrictive.

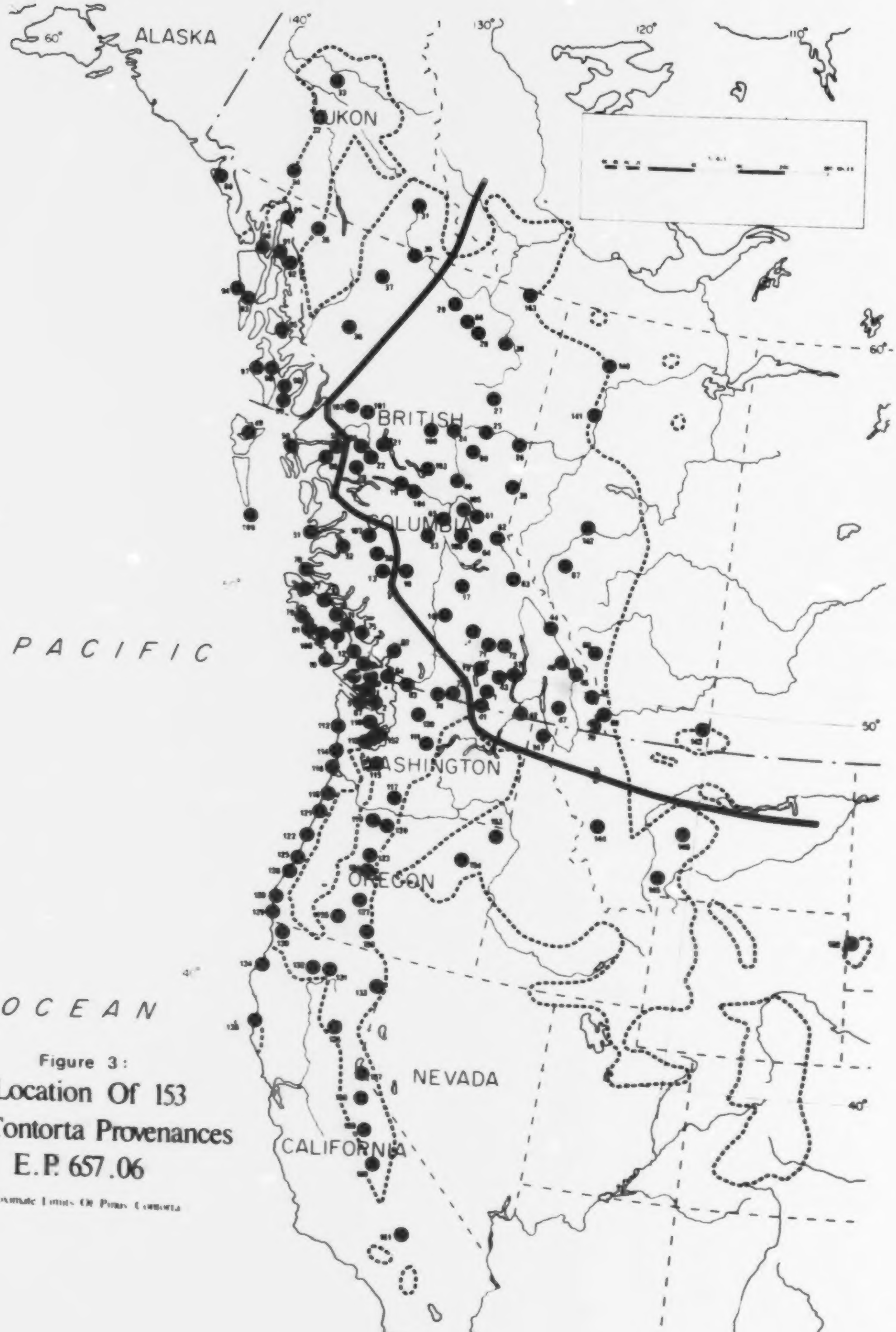

Figure 3:
Location Of 153
Pinus Contorta Provenances
E. P. 657.06

------- Approximate Limits Of Pinus Contorta

4. Cone production was assessed at 42 of the 60 sites (E.P. 637.06) in 1981, 8 years after planting (11 years from seed). Indications are that sites which are favourable to vegetative growth are also favourable to cone production, conceivably because, at this young age, the trees on the better sites have larger crowns.

5. A series of variance analyses on 6th year height of the provenance-family plantation at Red Rock (E.P. 699.04) revealed that the magnitude of variation of the provenance component increased rapidly as more provenances from a wider geographic area were included in the analyses, but the families-within-provenance component stayed relatively the same. This indicates that genetic variation for height growth resides mostly between provenances rather than among families-within-provenances.

6. Of immediate practical significance, 6 of the 10 tallest families (out of a total of 778 families) are from a single provenance, Larch Hills (#72) near Salmon Arm. A recommendation has been made to develop this Larch Hills source as a seed production area.

7. Fast growing provenances were also more vigorous and less susceptible to stem rust. Infestation among the 10 tallest provenances was 12%, as compared to the plantation average of 24%.

Table 9. Combined Analysis of Variance* of the 10 Standard Lodgepole Pine Provenances Over 55 Test Sites in 11 Geographic Regions.

| Source | DF | MS | F-Value | Variance Component | |
|---|---|---|---|---|---|
| | | | | Value | % |
| Regions | 10 | 79 203 | 113 | 785 | 37 |
| Sites/Regions | 44 | 17 744 | 37 | 863 | 40 |
| Provenances | 9 | 37 487 | 54 | 334 | 16 |
| Prov. X Reg | 90 | 698 | 1 | 22 | 1 |
| Prov. X Sites/Reg | 386 | 478 | 1 | 73 | 3 |
| Block/Site/Reg | 55 | 915 | 3 | 55 | 3 |
| Residual | 494 | 331 | | | |

*Analysis is based on plot means and assumes all effects random

## SITKA SPRUCE (E.P. 702) C.C. YING

White pine weevil attack was assessed in a provenance trial near Sayward. Forty-one percent of the living trees were attacked. None of the 38 provenances included in this trial was immune. However, percent of weeviled trees among provenances varied from 16 to 62. About 38 out of the 433 families were free of weevil attack. Four trees each from the 5 tallest weevil-free families have been selected for cloning and further testing of their putative resistance to the weevil.

Sitka spruce provenances from Oregon and Washington have outgrown local sources by more than 40%. After seven years in the field at sites on Vancouver Island and the Queen Charlotte Islands they show no indication of cold injury. Recommendations have been made to introduce Sitka spruce seeds from these provenances for the purpose of establishing more extensive pilot and seed plantations.

### NOBLE FIR (E.P. 857) C.C. YING

The objectives are to study geographic variation in this exotic species, and to determine its potential for planting at high elevation sites in the coastal region. Eleven of the 12 proposed test sites were prepared and planted in the fall of 1981. The sites represent a wide range of ecosystems, elevations and geographic conditions. Twenty-two seedlots are included at each site. Eighteen noble fir provenances are common to all sites, and one or two amabilis fir or western hemlock seedlots are also included.

## TREE BREEDING AND ASSOCIATED RESEARCH

### TREE IMPROVEMENT IN INTERIOR SPRUCES IN BRITISH COLUMBIA (E.P. 670) G.K. KISS

#### Strategy

The objective of this project, which was started in 1968, is to produce genetically improved spruce seed for reforestation. Since the project's inception, the strategy has comprised: phenotypic selection of plus trees; evaluation of the selected trees for their general combining ability, estimated from field tests of open-pollinated (o.p.) progenies; establishment of grafted seed orchards incorporating proven clones; generation of genetic information and the next breeding generation through controlled matings and full-sib testing.

#### Progeny Tests

Analysis and interpretation of survival and height data were completed for all o.p. trials. Some interim conclusions are:

1. Considerable within- and between-family variation augurs well for the genetic improvement of interior spruces, using the above strategy;

2. Family x site interaction for height growth is negligible, i.e. families tend to perform consistently in relation to each other, regardless of where they are planted;

3. Survival and height of progenies at all test sites varied inversely with source elevations of the parent trees;

4. Site has an overwhelming influence on the mean survival and growth of spruce families. In this regard, plantation productivity, in terms of mean height and survival, varied directly and substantially with the intensity of site preparation, especially with intensive cultivation (Table 10).

Table 10. Survival and Growth of Open-pollinated Progenies from the Prince George Selection Unit after Six Years.

| Plantation Location | Plantation Preparation | Survival No. (%) | Av. Ht. Growth per tree (cm) | Total Growth* (m) |
|---|---|---|---|---|
| Quesnel | Broadcast burn | 14 236 (86.7) | 55.7 | 7 929 |
| Barbie L. | Windrow, burn | 15 389 (94.3) | 65.1 | 10 018 |
| Red Rock | Ripping, discing | 16 133 (98.0) | 88.5 | 14 278 |

*Average seedling height x number of surviving trees

The three progeny tests are almost identical in design, content and habitat, differing primarily in degree of cultivation. The total growth at Red Rock is nearly 80% greater than at Quesnel, and the total volume production may well exceed four times that at Quesnel. Differences of this magnitude demand consideration of more general use of mechanical site preparation for the establishment, not only of spruce progeny tests, but also of operational plantations.

Three 1.5 generation production orchards have been proposed on the basis of progeny tests for the Smithers, Prince George and East Kootenay Selection Units, and propagation for these orchards is being carried out with scions harvested from clone banks at Red Rock Research Station.

### Controlled Crosses

Almost 4 000 seedlings were grown in PSB 415 styro-containers, employing accelerated growth techniques. The seed originated from pilot or trial matings made possible by precocious flowering in the breeding arboretum, as well as from open-pollinations from some of the original ortets (plus trees). The tested growth regime proved satisfactory for, during the 6 month period April 1 to September 30, average height of the 3 794 surviving seedlings reaching 26.8 cm.

Two traits, dwarfism and a form of chlorophyll deficiency, both apparently under the control of single genes, were tentatively identified in several full- and half-sib progenies. They will be described in a published note following repeat matings to corroborate observed segregation ratios for the expression of these traits, and to elucidate the nature of their genetic controls.

### Breeding Arboretum and Clone Banks

For the first year since grafts were moved to Vernon from Red Rock in 1976, only limited numbers of male and female flowers were produced in 1981. This is attributed mainly to heavy strobili production in the preceding year, coupled with cool, wet weather during the summer of 1980.

An additional 1 489 ramets were planted in the Barnes Creek clone bank, bringing the total number of ramets in this clone bank to 1 885. Survival and growth of the ramets planted in 1980 were excellent.

## BREEDING PROGRAM FOR COASTAL DOUGLAS FIR IN COASTAL BRITISH COLUMBIA

(E.P. 708) J.C. HEAMAN

The main thrust of this project is the production and field testing of pedigreed seedlings resulting from controlled matings between clones of selected trees. The test plantations, which are widely distributed across the Vancouver Forest Region, will be used for the selection of material for second generation production seed orchards and for continued breeding. At the same time they will generate information to guide the refinement of breeding strategies for the species. The data will provide estimates of additive and non-additive variance components, genotype x environment interaction effects and a ranking of parent clones by general combining ability to permit limited culling in first generation seed orchards. Progeny performance is being assessed in terms of height, volume and adaptability.

Controlled crosses using a 6-tree, disconnected, modified-diallel mating design have been made from 1973 to 1980. These have been grouped into manageable planting programs each year (Table 11). Each series of crosses has been planted at 11 test sites in four replications of 4-tree row plots. During 1981, 11 more sites were planted and there are now 77 sites in place. Currently, much of the work on this project is devoted to plantation maintenance, protection, assessment and consolidation of records.

In general, survival has been excellent, above the 95% level, and most of the mortality can be attributed to browsing by grouse, deer and rabbits. Early success in protecting the seedlings with open-ended milk cartons (Forest Research Review 1980/81) has led to protecting some 20 000 seedlings by this method. Heavy snow can cause problems, but the extra work is proving worthwhile.

In 1981, due to a severe shortage of reproductive buds on the clone bank at Cowichan Lake Research Station, no pollination program was carried out.

The project was reviewed in detail in 1981, both by the Breeding Strategy Subcommittee of the Coastal Tree Impovement Council and by Dr. C.J.A. Shelbourne. While alternatives were discussed, a general endorsement of the strategies was given. After reviewing the provenance work of E.P. 599, inclusion of more coastal United States material was agreed upon, and steps are being taken to achieve this objective.

Table 11. Summary of Progress in the Recurrent Selection Project

| Series | Sowing Year | Parents | Modified Diallel Groups | Crosses Planted | Test Sites |
|---|---|---|---|---|---|
| I | 1975 | 60 | 10 | 177 | 11 |
| II | 1976 | 30 | 5 | 99 | 11 |
| III | 1977 | 54 | 9 | 165 | 11 |
| IV | 1978 | 54 | 9 | 170 | 11 |
| V | 1979 | 48 | 8 | 153 | 11 |
| VI | 1980 | 48 | 8 | 140 | 11 |
| VII | 1981 | 18 | 3 | 55 | 11 |
| TOTALS | | 312 | 52 | 959 | 77 |

## THE LODGEPOLE PINE TREE IMPROVEMENT PROGRAM (E.P. 770) J.C. MURPHY

The first-phase selection of 565 lodgepole pine parent trees has been completed. All the trees have been grafted and established in breeding arboreta at Red Rock Research Station where, including the clonal materials originally selected by Swedish interests, a total of 775 lodgepole pine clones has now been accumulated.

The breeding arboreta are still not producing enough flowers to permit a meaningful pollination program, and it appears that they will not do so for at least a few more years. The oldest ramets were in their sixth growing season in 1981, and yielded an average of only 0.98 female conelets and 0.04 male clusters per living ramet.

Phenological observations were continued in a 9-year old bank of clones from north central B.C. and Yukon, and trial pollinations were also carried out. Female flower development of these clones is most active from mid-May to mid-June at Red Rock, the last 10 days of May being most critical for controlled pollinations. Similarly, this proved to be the most productive period in which to collect pollen.

The erection of a small-mesh fence to protect the breeding materials from rodent damage, particularly by snowshoe hare, has proved to be justifiable. A vigorous grass cover has been firmly established throughout the breeding orchards and clone banks, and will substantially reduce the need for weed control. Considerable effort was expended in attempting to control the spread of the Canada thistle (Cirsium arvense). The herbicide, Roundup, was effectively applied on a selective spot-application.

## PHOTOPERIOD EXTENSION FOR GROWTH ACCELERATION AND FLOWER PROMOTION IN LODGEPOLE PINE (E.P. 771) J.C. MURPHY

This study was established in 1976 to examine the effect of accelerated growth, induced by supplementary lighting, on the stimulation and enhancement of flower production by lodgepole pine seedlings and grafts. Wheeler (1979) reported experimental details and early results. Observations on growth and flower production are being continued.

After 5 years the percentage of flowering trees and the average number of seed cones per flowering tree were approximately six times greater for treated seedlings (81%, 18 cones per tree) than for controls (12%, 3.6 cones per tree). Differences in pollen cone production were of a like magnitude (Plate 5). Similar differences were also recorded in 1981 (Wheeler et al. 1982), confirming the potential benefits of accelerated growth treatments for advancing tree improvement programs in lodgepole pine (Plate 5).

Plate 5. Six-year old lodgepole pine clone, grown initially under continuous illumination for six months shown beside person and untreated clone in the foreground (EP 771).

## WESTERN HEMLOCK TREE IMPROVEMENT (E.P. 813) M.D. MEAGHER

Rigorous review of the hemlock breeding program by geneticists of the Ministry of Forests in collaboration with the Breeding Strategy Subcommittee of the C.T.I.C., led to a substantial revision of the breeding strategy for this species. The amended plan will address problems inherent in the original program resulting from: 1) difficulty in obtaining wind-pollinated seed for proposed progeny tests; 2) general lack of information on the genetic architecture of hemlock populations; 3) inadequate definition of breeding zone priorities, and 4) delayed creation of a second generation breeding population. Featured changes in emphasis and technology include:

1. Establishment of a priority breeding zone comprising low- to mid-elevations, west Vancouver Island and, to a lesser degree, adjacent zones;

2. Definition of a breeding population comprising some 500 parental selections, mainly from the breeding zone itself. Proportions to be included from other areas have been established;
3. Wood density will be included among the selection criteria and will form a basis for limited, preliminary culling of candidate parent trees;
4. Evaluation of parental selections through field tests of controlled crosses, rather than of open-pollinated progenies as originally proposed. This strategy will be facilitated by reliance upon flower induction techniques which have been shown to be particularly effective with western hemlock (Forest Research Review 1980/81:5). A partial diallel mating design will be used to generate progenies for testing and, concomitantly, a pedigreed second generation for future selections;
5. The ability to cull established clonal seed orchards, already restricted by a very incomplete seed inventory, will be further reduced by the revised strategy. However, this will be more than compensated by the significantly advanced production of a pedigreed second generation.

As far as possible an effort will be made to effect a smooth transition to the revised program, utilizing the considerable quantity of materials and information already available and still being generated.

Parent tree selection by CTIC agencies was continued to targets set within geographic and elevation zones by the tree breeder. Selection and propagation of an additional 128 trees brought the overall total in the seed orchard program to 1 250. Clonal lists of all seed orchards were reviewed and, where appropriate, revised on the basis of remeasurement and analysis of established provenance (Canadian Forestry Service) and progeny tests (Tahsis Company).

Since May 1980, three series of open-pollinated progeny tests have been established for varying proportions of the total numbers of trees selected in the south coast mainland, west Vancouver Island and Johnstone Straits selection zones, progenies from the latter being planted in March 1982. Survival in the first two series ranges from 75% to 96%.

Cross-pollinations were completed among 12 study trees in the Duncan - Cowichan area, Vancouver Island, to complete a diallel. The progenies will provide needed information on genetic control and correlations among parameters of interest in western hemlock. The seeds will be sown in April 1982.

## PROPAGATION AND SEED ORCHARD RESEARCH

### COMPATIBILITY TESTING OF DOUGLAS FIR ROOTSTOCKS (E.P. 648.02) I. KARLSSON

The search for compatible Douglas fir root stocks continued during 1981. Approximately 1 600 two-year old graft unions from 42 controlled crosses of selected parents were tested, using microtechniques, to determine their degree of graft compatibility. Some interim conclusions are:

1. Root stock crosses which exhibit high survival during stress conditions also show a higher degree of graft compatibility;

2. The degree of compatibility varies more among the test clones than among the rootstock crosses. Thus, compatibility among the 40 testers varied between 19% (clone 126) and 100% (clone 19). Among the 42 rootstock crosses, compatibility varied from a low of 44% to a high of 93% for the best cross (191 x 93).

The most compatible rootstocks in this testing program will be used as a source for rooted cuttings and will also be established in a plantation for further testing and breeding. A long-term study using the same 42 rootstock crosses was field planted in 1979. This trial will evaluate the validity of early testing for predicting delayed incompatibility.

### PROPAGATION OF YELLOW CEDAR BY ROOTED CUTTINGS FOR PRODUCTION PLANTING (E.P. 750) I. KARLSSON

Measurements of two high elevation plantations of rooted cuttings and seedlings, 2 and 4 years after planting, indicate high survival for both types of plants. The height growth of the cuttings was equal to that of the seedlings and was not affected by ortet age in these plantations where ortets up to 7 years of age were included. At the end of the second growing season in the field, most cuttings had assumed orthotropic growth, and there was no obvious difference between the seedlings and the rooted cuttings. The results show that rooted cuttings can be considered as an acceptable alternative for reforestation when seedling planting stock is in short supply. Therefore, for the second consecutive year, 75 000 cuttings of yellow cedar, using material from a hedging orchard, are being produced at Cowichan Lake Research Station for production planting.

### DIFFERENCE IN ROOT DEVELOPMENT BETWEEN SEEDLINGS AND ROOTED CUTTINGS OF DOUGLAS FIR (E.P. 779.06) I. KARLSSON

A study of root development has been started in a 15-year old Douglas fir plantation in which some trees were grown from rooted cuttings and some from seed. The objective is to observe differences in root form and root volume and to relate them to stem form, stability and cone production. Sample trees were excavated and the roots washed clean and measured. Preliminary observations indicate that distinct differences exist in root form and root volume between the two types of trees, and these markedly affect stability and cone production; for example, no cones have been observed on trees grown from cuttings.

## ROOT PRUNING IN DOUGLAS FIR (E.P. 780.02) I. KARLSSON

Previously, root-pruning in Douglas fir clonebanks was shown markedly to increase cone production (Forest Research Review 1976/77). In October 1975, another study was commenced to determine the long term effects of repeated root-prunings. A 1969 plantation of controlled crosses was root-pruned three times; October 1975, October 1978, March 1982. After the first root-pruning, some cones were observed on the treated trees but none on the controls. The second root-pruning was followed by a heavy cone crop on treated trees in 1980, with only sporadic coning on the controls. After the first two treatments the root-pruned trees are considerably smaller and have narrower crowns than the controls. Mean heights and crown widths, measured in the fall 1981, are shown in Table 12.

Table 12. Mean height and crown widths of 13-year old Douglas fir clones in response to repeated root-pruning.

| | Height (m) | Crown diameter (m) |
|---|---|---|
| Treated | 5.9 | 2.9 |
| Control | 7.5 | 3.7 |

Because of the larger area for carrying cones, it is possible that the control trees now reaching the age of natural cone production will, in one or two years time, surpass previous and current cone production of root-pruned trees. In this eventuality, root-pruning could only be recommended as a short-term measure where early flowering is required.

## IMPROVING CULTURAL TECHNIQUES FOR THE PROPAGATION OF NORTHWEST CONIFERS (E.P. 948) A.M. WOOD

The solution of cultural problems is an integral part of the operational grafting program at Cowichan Lake Research Station. One study aims to identify the growing medium and container type best suited for optimum rootstock and scion growth of Douglas fir, western hemlock and amabilis fir.

## GROWTH ASSESSMENTS OF ROOTSTOCKS AND GRAFTS IN TWO GROWING MEDIA AND TWO CONTAINER DESIGNS (E.P. 948.01) A.M. WOOD

The test media are: 3 peat:2 perlite:1 sand and 1 peat:2 perlite. Containers are: round nursery pots (3.2 ℓ) and square pots (4.5 ℓ) with ribbed walls and an open mesh bottom. Root and shoot growth of rootstocks and grafted trees are being assessed.

Half the ramets will be transplanted into nursery beds, and the other half will be transplanted into larger pots for further study.

Since the experimental stock is part of the production grafting program, the grafts will be turned over to the propagation program at the completion of the study, and the results will be immediately incorporated into operational procedures.

## EFFECT OF ROOTSTOCK PRUNING ON GROWTH AND DEVELOPMENT OF GRAFTED TREES (E.P. 948.02) A.M. WOOD

Rootstock pruning affects root development and subsequent growth of grafted trees. Previously, the amount of pruning has been left to the discretion of the propagation staff.

The objective of this study is to determine the intensity of pruning needed to obtain high quality grafts with well balanced shoot/root ratios. Western hemlock, amabilis fir and Douglas fir are included in the experiment. The four treatments applied to the rootstocks are: light, moderate and heavy pruning and, as a control, no pruning.

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## ACTIVE EXPERIMENTAL PROJECTS

| | | |
|---|---|---|
| E.P. 474 | Inbreeding and sterility studies with Douglas fir, Cowichan Lake | F.C.H. Yeh |
| E.P. 479 | Plus tree selection and registration of Douglas fir | J.C. Heaman |
| E.P. 513 | Racial crosses with Douglas fir | J.C. Heaman |
| E.P. 599 | Coastal Douglas fir provenance study | C.C. Ying |
| E.P. 611 | Jennis Bay reforestation trials | C.C. Ying |
| E.P. 646 | Effects of altitudinal and latitudinal displacement of white and Engelmann spruce provenances: Prince George plantations | B. Jaquish |
| E.P. 648 | Grafting in Douglas fir | I. Karlsson |
| E.P. 657 | Variation in lodgepole pine with particular reference to British Columbia | C.C. Ying |
| E.P. 662 | An altitudinal test of a low elevation seed source of Engelmann spruce, Larch Hills and McGillivray Lake | M.B. Clark |

| | | |
|---|---|---|
| E.P. 670 | Tree improvement of interior spruces in British Columbia | G.K. Kiss |
| E.P. 672 | Effects of altitudinal and latitudinal displacement of white and Engelmann spruce provenances: Prince Rupert plantations | B. Jaquish |
| E.P. 688 | Douglas fir provenance plantations, Prince George Forest Region | L.J. Herring |
| E.P. 692 | Shore pine spacing and provenance trial | C.C. Ying |
| E.P. 699 | Propagation and evaluation of lodgepole pine breeding material | C.C. Ying |
| E.P. 702 | Geographic variation in Sitka spruce | C.C. Ying |
| E.P. 705 | Spruce Piceta Chilliwack and Red Rock | G.K. Kiss |
| E.P. 707 | Progeny test of coastal Douglas fir in coastal British Columbia | J.C. Heaman |
| E.P. 708 | Breeding program of coastal Douglas fir in coastal British Columbia | J.C. Heaman |
| E.P. 710 | Interior Douglas fir breeding arboretum | C.C. Ying |
| E.P. 711 | Western larch breeding arboretum | C.C. Ying |
| E.P. 750 | Yellow cedar plantation at Cowichan Lake Research Station | I. Karlsson |
| E.P. 770 | Lodgepole pine tree improvement program | J. Murphy |
| E.P. 771 | Photoperiod extension for growth acceleration and flower promotion in lodgepole pine | J. Murphy |
| E.P. 776 | Correlations between quantitative and qualitative attributes | F.C.H. Yeh |
| E.P. 778 | Experimental population genetics in conifers (Electrophoresis) | F.C.H. Yeh |

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|---|---|---|
| E.P. 779 | Nursery experiments at Cowichan Lake Research Station | I. Karlsson |
| E.P. 780 | Flower stimulation in Douglas fir | I. Karlsson |
| E.P. 813 | Western hemlock tree improvement for coastal British Columbia | M.D. Meagher |
| E.P. 815 | Amabilis fir arboretum | I. Karlsson |
| E.P. 823 | Grand fir provenance study | C.C. Ying |
| E.P. 824 | Amabilis fir provenance study | C.C. Ying |
| E.P. 857 | Noble fir provenance study | C.C. Ying |
| E.P. 871 | Intensive forestry practices and wood quality | K. Illingworth |
| E.P. 948 | Improving cultural techniques for the propagation of northwest conifers | A.M. Wood |

## ECOLOGY AND EARTH SCIENCES

Major emphasis in the section was expansion of the Fish/Forestry, Wildlife Habitat and Range research programs. Much of the expansion was due to the cooperative nature of many of the projects which were initiated. This has ensured that the greatest benefit from available expertise is realized and that all interests are considered.

Dave Toews and Jack Cheng filled the Regional Research Hydrologist positions in the Nelson and Kamloops Forest Regions respectively. The year was spent developing a research program, 5 year plan and consulting for regional staff.

Dick Annas resigned his position as Provincial Ecology Coordinator. Correlation of the ecosystem classification was continued by regional program staff as time permitted.

### ECOLOGY AND ECOSYSTEM CLASSIFICATION

#### ECOSYSTEM CLASSIFICATION PROGRAM (E.P. 822) R.M. ANNAS AND A. NICHOLSON

Activities in the ecosystem classification program continued to focus on the production of regional plant guides and operational reports, and on regional training activities. A series of workshops relating to various aspects of ecology were well received by program staff at the annual meeting.

Work at headquarters concentrated primarily on a problem analysis of grassland classification and correlation. In addition a problem analysis of the incorporation of alpine tundra and subalpine parkland areas into the ecosystem classification system was initiated. Progress was made on a taxonomic reference list and plant collecting - herbarium procedures manual.

The map legend for the Biogeoclimatic Zones of British Columbia has been completed and the map is in the final stage of production. The Forest Ecology Section has been written for the revised UBC Forestry Handbook and primarily includes descriptions of each zone.

#### ECOSYSTEM CLASSIFICATION IN THE VANCOUVER FOREST REGION (E.P. 822.01) F.C. NUSZDORFER

As part of the ecosystem classification program, data from 350 plots were analysed. Ecosystem associations were classified using the standard phytosociological method as well as ordination. Soil data were grouped by ecosystem association to give means, standard errors, minimum and maximum values for the measured chemical and physical properties. Environmental data were also analysed. Using results of the above analyses biogeoclimatic mapping of the northern part of the Vancouver Forest Region was started.

## ECOSYSTEM CLASSIFICATION IN THE NELSON FOREST REGION (E.P. 822.02) G. STILL AND M.V. KETCHESON

Field sampling at the reconnaissance level has been completed for the entire region. New computer facilities have been installed in Nelson, which now enables the editing and processing of the data. Toposequences, edatopic grids, ecosystem associations and management interpretations have been finalized for nine of the subzones in the Region (PPBG, IDFf, MSa, MSb2, ICHb, ICHc, ESSFa, ESSFb, ESSFe2)[1]. The data collected from the ICHa, ESSFc and IDFg are being processed and these additional subzones should be finalized before the 1982 field season.

Ministry and industry personnel were given ecosystem classification workshops in May and June 1981 at Grand Forks, Castlegar, Nelson, Cranbrook, Invermere, Golden and Revelstoke. Training courses have been updated and revised for presentation in 1982. The field aid (FS 238 form) entitled "Estimating Soil Texture in the Field" was prepared for use by operational staff.

## ECOSYSTEM CLASSIFICATION IN THE KAMLOOPS FOREST REGION (E.P. 822.03) W.R. MITCHELL

An office manual is being finalized for the western portion of the Kamloops Forest Region. A first draft will be available for distribution to the districts in 1982. The office manual will be used in conjunction with the field guide and will provide additional documentation, characterization and interpretations of biogeoclimatic and ecosystem units. Biogeoclimatic unit (subzone and variant) maps at a scale of 1:500 000 and 1:125 000 have been available for regional and district use.

Ecological field sampling and data synthesis are complete for the northeastern part of the Kamloops Forest Region. Biogeoclimatic unit maps at a scale of 1:100 000 are available for field use.

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[1] Refer to p. 144 for listing of Biogeoclimatic Units.

Field sampling will continue in the southeast part of the Kamloops Forest Region in 1982. Tentative Biogeoclimatic Unit maps at a scale of 1:100 000 are available for field use.

Approximately 250 ministry and industry personnel were trained in the identification and interpretation of ecosystems for use in resource management. Emphasis was on field application of ecosystem classification. In addition, 125 UBC students were trained in the identification of ecosystems for resource management.

## ECOSYSTEM CLASSIFICATION IN THE CARIBOO FOREST REGION (E.P. 822.04) W.J. WATT

Field sampling for the ecosystem classification program continued in the SBSb and limited sampling of zonal sites in the northern SBSa, west of Quesnel. Minor fill-in sampling was carried out in previously sampled subzones. Wetland ecosystems of the IDFb were sampled by the regional range section.

Classification of the ESSFh was updated using new samples from the northern part of the region. A preliminary classification of the SBSc was developed and with the assistance of plot data from the Kamloops Forest Region the IDFa in the Cariboo was classified.

A field guide and an office report on the identification and interpretation of ecosystems are nearing completion for the area east of the Fraser River. These reports classify seven subzones and present interpretations for forest management, range management and engineering.

Training sessions and small workshops were used to familiarize Ministry staff with completed classification work and in turn develop interpretations for forestry and range management. A total of 16 staff participated in the training sessions for a total of 32 person-days.

The ICH subzones were correlated with those of the Prince George Forest Region. Some reconnaissance checking of the Montane Spruce Zone was carried out in the southwest of the region to assist in preparing the provincial biogeoclimatic zone map.

## ECOSYSTEM CLASSIFICATION IN THE PRINCE RUPERT FOREST REGION (E.P. 822.05)
J.J. POJAR

Data collection continued on schedule with field sampling concentrated in the CWH of the Mid-Coast and Queen Charlotte Island Timber Supply Areas, as well as selected portions of the SBS, CWHf, ICHg, and higher elevations (ESSF and MH). Field work for interpretations was carried out primarily in the CWH throughout the region.

Draft operational reports were produced for the CWHf, the ICHg, the Mid-Coast CWH (h and i), and the SBS Zone. To accompany these reports, two field guides to the identification of common plants were produced, one for the Skeena area (CWHf and ICHg) and one for the SBS Zone. Also, a summary of selected silvics for the important tree species of the Prince Rupert Forest Region was compiled. Classification correlation with other regions continued.

Training (introductory sessions and field workshops) took place in the Terrace, Hazelton, Bella Coola, Smithers, Houston, and Burns Lake Forest Districts. The Regional Management Team took part in a training session. Training aids and packages have been assembled for each District.

Consultants extended the Ministry of Forests system of ecosystem classification to areas of Tree Farm Licences 2 and 24 on the Queen Charlotte Islands. Collaboration took place with MacMillan Bloedel Limited in classification work on TFL 39 on the Queen Charlotte Islands. The draft operational report for the CWHg of the Queen Charlotte Islands is nearing completion.

## ECOSYSTEM CLASSIFICATION IN THE PRINCE GEORGE FOREST REGION (E.P. 822.06)

D.V. MEIDINGER

Field sampling and biogeoclimatic mapping has been completed for the low-elevation subzones in the Rocky Mountain Trench area southeast of Prince George. A first approximation operational report is nearing completion for this area (SBSh, ICHf, ICHj and ICHk subzones). A comprehensive training program has been developed and introductory sessions (office and field) were initiated in the McBride Timber Supply Area (TSA).

Reconnaissance and field sampling were initiated in subzones of the Sub-Boreal Spruce Zone in the Prince George East and West Districts. A preliminary classification of the ecosystem associations in the SBSc, SBSf and SBSe subzones in the Prince George Forest Region is being prepared.

As a result of field work conducted under the Northern Fire Ecology Project (E.P. 868), reconnaissance level classification reports are being prepared for the Fort Nelson TSA and the northern portion of the Mackenzie TSA. A more detailed operational report is being prepared for the Ft. Nelson Lowlands Variant of the BWBSa.

## ECOLOGICAL INVESTIGATION OF WILDFIRES IN NORTHERN B.C. (E.P. 868)

D.V. MEIDINGER, J.J. POJAR AND R.L. TROWBRIDGE

The Northern Fire Ecology Project, which was initiated in the Fort Nelson TSA in 1980, was extended to the Cassiar and northern Mackenzie TSA's in

1981. The main contribution by the Research Branch to this project continues to be the reconnaissance level ecosystem classification of these areas. This supplies Protection Branch with an ecological framework upon which to base their fire ecology sampling.

Reconnaissance level classification reports are being prepared by the appropriate regional ecosystem classification personnel.

## VEGETATION SALINITY RELATIONSHIPS IN CHILCOTIN WETLANDS (E.P. 882) C. MAYALL

The objective of the project is to determine the relationship between salinity and vegetation in the meadow (water tolerant grass forb) component of Chilcotin wetlands.

At 134 sites, species composition was noted and soil samples were taken. The soils were later analysed for electrical conductivity and soluble calcium, magnesium, sodium, potassium, chloride, sulphate, carbonate and bicarbonate. From these parameters an approximation could be made of sodium adsorption ratio and exchangeable sodium percent.

The data are now being analysed using several techniques. Tabular analysis of the floristic data was facilitated by use of the Ceska-Roemer computer program. Two species groups [those including 1) *Juncus balticus* (*arcticus* Willd.), *Taraxacum officinale* and *Ranunculus cymbalaria* and 2) *Carex praegracilis* and *Aster pansus*] show fairly broad distributions ecologically, occurring in combination with all, and all but one other species groups, respectively. The species group comprised of *Suaeda depressa*, *Distichlis stricta* and *Scirpus nevadensis* generally occurs alone and is probably indicative of saline or alkaline conditions. Principal components analysis, canonical correlations analysis and cluster analysis were used to clarify the relationships between species distributions and soil parameters.

## AN ECOSYSTEMATIC APPROACH TO SILVICULTURAL MANAGEMENT OF IMMATURE FORESTS - SAYWARD FOREST STUDY (E.P. 930) R.N. GREEN

The study was initiated to provide resource managers with basic ecosystem information and interpretations. This information will be provided through the classification and integration of ecosystems of the Sayward Forest.

### Ecosystems of the Sayward Forest - their Description and Interpretation (E.P. 930.01)

A demonstration of ecosystem mapping (Scale - 1:10 000) was completed on a 1 500 ha block between Pye and Stella Lakes in the northeast portion of the Sayward Forest. The ecosystem units were integrated to form an interpretive map of silvicultural treatment units. A report explaining the results and applications of ecosystem classification and mapping was initiated.

Stand Description and Mapping for Operational Planning (E.P. 930.02)

Stand mapping and sampling was completed for the same 1 500 ha block described above. The final stand map has been draughted at a scale of 1:10 000. Tables of stand attributes and recommended treatments and a final report explaining methodology and application are in preparation.

Forest Humus Forms in the Sayward Forest in Relation to Properties, Genesis and Forest Productivity (E.P. 930.03)

Data analysis is in its final stages and a report is in progress.

## A PROBLEM ANALYSIS OF GRASSLAND CLASSIFICATION (E.P. 931) A. NICHOLSON

The objective of the project is to report on the description and classification of grasslands and their incorporation into the Ministry of Forests' ecosystem classification program.

A small workshop and field trip was conducted in June 1981 to enable an information exchange by participants from the ecosystem classification program and individuals from outside agencies possessing particular expertise in grassland ecology and classification. At present vegetation and soils data are being analysed and incorporated with existing regional data.

Plate 6. Data from the 1981 field season is now being analysed and incorporated with existing regional data (EP 931).

### ECOSYSTEM ASSOCIATION MAPPING IN THE TRUAX BASIN OF THE KAMLOOPS FOREST REGION (E.P. 942) W.R. MITCHELL AND R.D. WINKLER

The objective of this project is to develop a methodology, and map forest ecosystems. Truax Creek watershed, a 5 600 ha drainage basin located southwest of Goldbridge, was selected for detailed survey during the summer of 1981. The investigation involved the verification of biogeoclimatic boundaries and the mapping of ecosystem associations and phases as they occur over unique segments of the landscape. Field mapping on aerial photographs was at a scale of 1:19 000 and a final map was produced at a scale of 1:31 000.

Map units and corresponding management guidelines are described in a pending publication. The report describes the method used in the mapping of Truax Creek as well as the results of actual field work.

## SILVICULTURE AND HARVESTING SUPPORT

### DEVELOPMENT OF A FOREST WATER BALANCE MODEL FOR USE IN STAND MANAGEMENT (E.P. 855) T.A. BLACK

The objective of the project is to develop a forest water balance model that provides information on tree water stress. Work has been conducted in two 31-year old Douglas fir stands exposed to soil water deficits, near Courtenay. One stand has not been managed (1 840 stems/ha), while the other has been thinned to 840 stems/ha.

The water balance model, which uses a net radiation based evapotranspiration relationship, can accurately simulate root zone water storage in both stands. Recently, evapotranspiration calculated from stomatal and boundary layer conductance characteristics, leaf area and vapour pressure deficit has been incorporated in the model. Stand water use can then be partitioned between the trees and the salal (Gaultheria shallon Pursh) understory. Competition for soil water by the understory is considered to contribute to the observed similar growth in the thinned stand with understory and in the unthinned stand with no understory.

The focus of present research is the effect of understory removal on tree water use and stress. Total soil water potential and pre-dawn twig xylem pressure potential of trees, where understory was removed, has been found to be less negative (less stress) than for trees where understory remains. Root zone water storage measurements indicate trees, where understory has been removed, extracted nearly as much water as in similar areas where both trees and understory grew. Stomatal conductance of trees where understory was removed, was found to be higher than that of trees where understory grew. Because stomatal conductance affects photosynthesis as well as transpiration, preliminary results suggest understory removal can increase tree growth.

The distribution of water stored in the root zone is an important consideration in the development of the water balance model. In 1981, plots of different stand density and tree size were selected to determine differences in tree water use and growth. Such measurements are important in testing the accuracy of the model in simulating root zone water storage and tree water stress.

## DETERMINATION OF TRANSPIRATION RATE OF DOUGLAS FIR TREES USING THE HEAT PULSE TECHNIQUE (E.P. 855.02) Y. COHEN, T.A. BLACK AND F.M. KELLIHER

The measurement of transpiration rate of the tree is necessary in the study of tree water relations and growth. The objective of this study was to apply the heat pulse technique for the determination of transpiration rate in Douglas fir trees. The research was conducted at the University of British Columbia Research Forest near Haney and at a research site near Courtenay. A laboratory study was also undertaken at the same time to: 1) determine the relevant physical properties of the stem; and 2) calibrate the technique for use in Douglas fir.

Laboratory measurements indicated that the technique consistently underestimates the water flow in the stem by about 50% for any range of water flow. This is expected because of the interruption of water flow by the presence of the heat pulse probes. Measured transpiration rates of 19 cm dbh trees corrected using the laboratory correction factor, were found to be in good agreement with foliage transpiration rates calculated using a vapour diffusion model. However, data for the vapour diffusion are difficult and considerably more expensive to obtain.

A microcomputer system, using an Intel 8085 microprocessor, was developed to calculate and print out flow rate immediately following each field measurement. This will enable the forester to make a rapid assessment of transpiration rate in the field.

## THE EFFECT OF FERTILIZERS ON SELECTED ECOSYSTEMS IN THE CDF AND CWH BIOGEOCLIMATIC ZONES (E.P. 881) J. OTCHERE-BOATENG

This study was initiated to investigate the nutrient status of ecosystems under different fertilizer treatments. The movement and chemical changes of the fertilizers were also studied.

### Mineral Nitrogen in Field Forest Soils Following Application of Different N Fertilizers (E.P. 881.02)

Field soils were sampled and analyzed for their extractable mineral N contents for a period of 685 and 475 days following fall (1979) and spring

(1980) N applications, respectively. In the fall application urea fertilizer at the rate of 224 kg N/ha (and in some plots also 448 kg N/ha) was applied. However in the spring, adjacent plots were individually applied with urea, $NH_4NO_3$ or $(NH_4)_2SO_4$ fertilizers at the rate of 224 kg N/ha.

Fall Application: Mineral N levels increased initially in the LFH and top 10 cm mineral soils. Quantities of mineral N increased with levels of application. In most cases, the increases were larger than the amounts of N applied. Higher mineral N levels were maintained over the untreated plots in all sites for at least 200 days following application. Mineral N was predominantly in $NH_4$-N form for a minimum of 274 days after treatment. Mineral N in the treated soils dropped to the levels in the untreated plots by the end of 785 days.

Spring Application: Like the fall treatment mineral N levels in the soils were increased by the application of the N fertilizers. Large quantities of $NO_3$-N were extracted at least in the first 10 days in the LFH and mineral soils of the $NH_4NO_3$ treated plots. The $NO_3$-N levels in the latter plots declined to those of the untreated plots within 64 days after treatment. Ammonium predominated in the urea or $(NH_4)_2SO_4$ treated plots. Ammonium-N contents were relatively larger in the top mineral soils during the first 64 days after treatment in the $(NH_4)_2SO_4$ treated plots than the other N-applied plots. Most of the N-treated plots maintained high levels of mineral N in the organic and top mineral layers throughout the first 152 days following fertilization.

### Effect of Nitrogen Fertilizers on Some Soil Properties (E.P. 881.03)

The study evaluated the effects of nitrogen fertilizers on soil pH, cation exchange capacity (CEC) and exchangeable cations. Samples (LFH and top 10 cm mineral soil) taken 10 days after the fall urea treatments (224 or 448 kg N/ha) showed increases in pH and CEC. Exchangeable Al and Zn decreased considerably as a result of the urea application. Manganese was also decreased in most sites. Effect of urea on Na, K, Mg and Ca was not consistent. Soil pH continued to be higher in the treated plots than the untreated plots for a period of about a year in soils with low nitrifying capacity and for about 163 days where nitrification was high.

In the spring N treatments urea fertilized soils (except in the alder-conifer site) showed increases in CEC of the LFH samples taken 64 days after N application. LFH of the $(NH_4)_2SO_4$ - treated plots had some CEC decreases. The soil pH increase by urea fertilizer were smaller in the spring than in the fall treatment. The pH increases (over the untreated plots) were maintained in the LFH for a period of about 64 days in the spring application. There was no consistent and significant pH differences between the untreated, $NH_4NO_3$ or $(NH_4)_2SO_4$ plots. Probably because of lack of sufficient moisture immediately following the spring applications, the mineral soils were less affected by the N fertilizers in the spring than in the fall.

### Effects of Urea, $NH_4NO_3$ and $(NH_4)_2SO_4$ Fertilizers on Soil Capacity to Mineralize Nitrogen (E.P. 881.04)

Soil samples (LFH and top 10 cm mineral soil) were collected from untreated (check) and nitrogen-treated plots in each of six ecological units (sites) in the Sayward Forest to study the effects of N fertilizers on nitrification and N mineralization. Each of the 6 units had the following treatment plots: untreated, fall urea, spring urea and spring ammonium nitrate ($NH_4NO_3$). On 4 of the units, spring ammonium sulphate ($(NH_4)_2SO_4$) treatment plots were included in the design. The rate of application was 224 kg N/ha.

Two series of 42-day aerobic incubation studies were conducted immediately following sampling in mid-November 1980 and end of August 1981. Sampling for the 1980 study was 362 and 152 days after the fall and spring field N treatments, respectively. The comparable dates for the 1981 study were 685 and 475 days, respectively.

In general, soil samples from a red alder - Douglas fir site behaved differently from those from the other sites. Nitrogen mineralized in the control plots (except in the alder - Douglas fir site) and some of the N treated non-productive (N poor) sites was mostly in the $NH_4$-N form in both the 1980 and 1981 studies. Net nitrification was found to be negative in all untreated mineral soils from N poor sites. In the 1981 study, net nitrification in the untreated LFH was positive only in the samples from the alder - Douglas fir site.

The 1980 and 1981 incubation studies showed general increases in net nitrification or mineralization in the LFH and mineral soils of most N-treated plots except soils of the alder - Douglas fir plots. Results of the 1981 study indicated that urea-treated LFH materials have less capacity to net-mineralize N than the material fertilized with $NH_4NO_3$ or $(NH_4)_2SO_4$. Net nitrification, on the other hand was generally larger in the urea-treated plots than the other plots. There were substantial reductions in net mineralization and nitrification in soils from the alder - Douglas fir site by all the N treatments. On the whole, large quantities of N were mineralized in samples from N-rich sites than those from N-poor sites.

### N Fertilizer Effects on Foliar Elemental Concentration, Dry Foliage Mass and Shoot Growth (E.P. 881.05)

The study assessed foliar-nutrient status of 41-year-old Douglas fir stands from 6 selected ecological units in the Sayward Forest before and after N fertilization. Adjacent plots in each site were individually fertilized with urea in the fall (November 1979), or with urea, or $NH_4NO_3$ or $(NH_4)_2SO_4$ in late spring (June 19809). Rate of fertilizer application was 224 kg N/ha. Post-fertilization sampling of foliage and shoots was done in late October 1980. Second growing season samples were taken in November 1981.

First growing season results:

Foliar N was found to be deficient (about 1.0%) only in the low - site stands. Level of P, S, Ca, Mg, K, B, Mn and Zn were sufficient for tree growth. Concentrations of Fe and Cu were low and possibly deficient, but further work in needed to confirm these.

Preliminary data suggest that all the N fertilizers were able to alleviate the foliar N deficiencies in the poor sites. Foliar P levels, however, were decreased by N fertilization. Total S concentrations were increased where $(NH_4)_2SO_4$ fertilizer was applied. The concentrations of the other elements were not changed significantly by the fertilizers. Whereas samples from the non-productive sites showed increases in dry foliage mass and shoot-length growths following the fall (and some spring) N fertilization, those from the N-rich sites did not. The data agreed with N mineralization and nitrification potentials of the study sites.

Second growing season results:

Like the preliminary results (E.P. 881.05), N fertilizers did not change the concentrations of Ca, Mg, K, B, Mg and Zn in the current year's needles significantly. Phosphorus concentrations though reduced by N treatments were not statistically different from those of the untreated plots. Foliar N concentrations in the current needles showed significant increases over those of the control plots. Plots treated with $NH_4NO_3$ or $(NH_4)_2SO_4$ fertilizers had the highest N concentrations in the current needles than those treated with urea (in the fall or spring).

Nitrogen fertilizers also resulted in significant increases in both the current and previous year's needle mass. Though the mass of the current foliage of trees on the $NH_4NO_3$-treated plots was larger, it was not significantly different from the foliage mass of the other N treatments. Growth of the current shoots was greater in the second year (1981) following fertilization than in the first year. The largest growth in 1981 occurred on $NH_4SO_3$ and $(NH_4)_2SO_4$ plots. In the 1981 growing season, increases in shoot growth (current) resulting from N applications ranged from 36% to over 300% depending on site and N treatment. Foliage mass and shoot extension during 1980 were largest for trees on the fall urea-treated plots. During the two growing seasons (1980 and 1981), spring urea application resulted in the smallest increases in needle mass and shoot growth. This may be due possibly to high N volatilization and immobilization of the urea in the warmer season.

## THE SIMULATION OF LANDSAT-D AND AN ASSESSMENT OF ITS CAPABILITIES FOR THE INVENTORY AND ASSESSMENT OF WETLANDS FOR MANAGEMENT PURPOSES (E.P. 905)

G.F. TOMLINS

The objective of this project is to evaluate the potential of Landsat-D Thematic Mapper (TM) data for ecosystem classification, inventory and management of wetlands. The TM is a novel sensor which will be carried aboard the next Landsat satellite scheduled for launch in July 1982. The TM will acquire data in seven discrete wavelength bands at a ground resolution of approximately 0.1 ha.

An area in the Cariboo-Chilcotin wetlands southwest of Williams Lake was selected for study. Airborne multi-spectral scanner imagery of the area was acquired in August 1981. This imagery as been digitally processed to simulate the design parameters of the TM data. The configuration of the airborne scanner has allowed for the simulation of TM bands 1, 2, 3, 4 and 6 (see Figures 4 and 5 for the corresponding wavelengths).

Field data acquired in 1980 were updated during a second field visit in August 1981, three days after image acquisition. Wetland class units in the vicinity of Fletcher, Willan and Kloakut Lakes were mapped from these data at a scale of 1:25 000. These maps have provided training data for the digital classification of the simulated satellite data set.

Figures 4 and 5 show that discrimination of individual wetland and transitional wetland classes requires simultaneous consideration of spectral reflectance in all five of the TM bands under investigation. Although not shown in these graphs, it has been found that the marsh and shallow water classes are readily differentiated using the TM data.

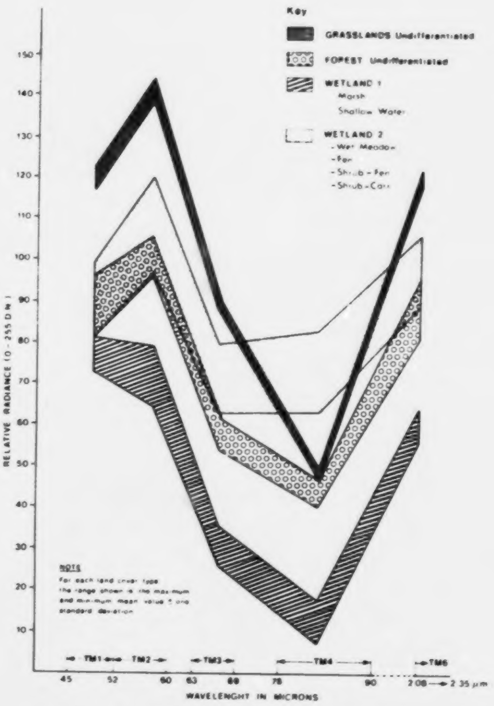

Figure 4 LAND COVER DISCRIMINATION IN THEMATIC MAPPER BANDS
FLETCHER LAKE TRAINING AREA
B.C. RESEARCH 1982

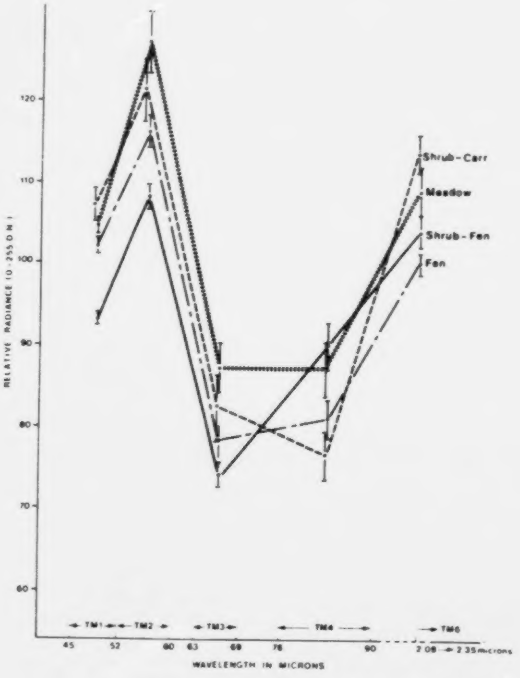

Figure 5 WETLAND CLASS DISCRIMINATION IN THEMATIC MAPPER BANDS
FLETCHER LAKE TRAINING AREA
B.C. RESEARCH 1982

The entire study area has been classified using the GEMS digital image analysis system at the Pacific Forest Research Centre. A thematic map is being prepared from the digital classification. Map classification accuracy will be determined during a final field visit.

Wetland and transitional wetland units can be shown by the various hues of yellow to light green, ranging from the drier shrub-fen and shrub-carr complexes (yellow to yellow-green) to the wet meadow and fen units (light to mottled green).

## SOIL STABILITY ON THE QUEEN CHARLOTTE ISLANDS (E.P. 782) D.J. WILFORD AND J.W. SCHWAB

This project was initiated in 1976 to study landslides in the Rennell Sound area of the Queen Charlotte Islands. The objectives were: to inventory landslides in forests, clearcuts and roads; to determine characteristic features of failure sites; and to provide recommendations for forest management. It was found that by identifying mass movement processes, characteristic failure sites can be described. Slope gradient, soil moisture, landform, terrain features, land use practices and in some cases minor vegetation are the significant site factors describing potentially unstable sites. Importance of these factors varies for each mass movement process reflecting the difference in moisture status and level of confinement of the moving material. A summary report has been completed. Training sessions have been given to Ministry of Forests District staff.

Two other reports are in preparation as a result of the research, one dealing with mass movements in Rennell Sound during the October/November 1978 storm. The mass wasting triggered by this storm presented an opportunity to compare mass wasting on man-modified terrain to forested terrain. The storm generated 264 mass movements in the Rennell Sound area: 113 in forested terrain, 126 in clearcut units and 25 from roads. Debris avalanche activity disturbed 64 ha or 0.4% of the steep land. In addition debris torrents scoured 22.3 km of stream channels. Mass movement frequency for clearcut units and roads is respectively 14 times and 25 times the rate on forested terrain. The other report deals with the classification of mass movements.

## SLOPE STABILITY OF NEMO AND WEE SANDY CREEK BASINS, SLOCAN LAKE, SOUTHEASTERN B.C. R.T. PACK

A survey of various factors controlling landslide occurrence was conducted in two major and two minor eastward-draining basins in the Valhalla Mountains of the Nelson Forest Region in conjunction with the Science Council of B.C.

and the Department of Geological Sciences, University of British Columbia. The study attempted to predict possible impacts of forest engineering activities by (1) examining the distribution and properties of fundamental factors which contribute to the stability of slopes in the study area, (2) examining landslides caused by forest engineering in similar natural environments of the region, (3) developing and implementing a simple landslide hazard classification scheme for use by forest managers, and (4) producing a 1:20 000 scale landslide hazards map.

Landslides were found to be primarily controlled by interactions of slope inclination, groundwater, soil shear strength, tree root cohesion, and soil depth. Eight types of stability problems associated with road construction on slopes in various states of equilibrium have been identified. Landslides resulting solely from loss of tree root cohesion following clear cutting were seldom encountered.

Slopes were classified according to a semi-quantitative analysis of natural slope equilibrium and evidence of past instability. Forest engineering interpretations were based on the observed behaviour of slopes in similar states of equilibrium.

## SOIL WATER REGIMES ON A FORESTED SLOPE (E.P. 902) D.G. GILES

The objective of this study is to determine the time course of root zone water storage during the year at different positions on a forested slope of varying productivity. The study is being carried out at eight established plots in an almost mature forest at the Cowichan Lake Research Station, Vancouver Island. The plots are located on the northwest slope of Mesachie Mountain, over a transect length of 750 m, and at elevations between 180 and 300 m asl.

Soil moisture and meteorological data have been collected continuously since June 1980. This has provided 17 months of data for calculating time course water balances which are being compared to site productivity variations.

Soil moisture retention studies, both field and laboratory, have been carried out to provide the necessary data for calculating evapotranspiration under soil moisture limiting conditions. In addition, other soil physical properties pertinent to the present study have been reviewed. These include saturated hydraulic conductivities, bulk densities and particle size measurements. Practical determinations of rainfall interception have been carried out at representative sites for developing interception functions to be incorporated in the water balance equations.

## SOIL TEMPERATURE RESEARCH (E.P. 920) R.L. TROWBRIDGE AND K. MCKEOWN

The object of this research is to help characterize subzones in the Prince Rupert Forest Region by their soil temperature and to study soil temperature relationships between forested sites and clearings.

Twenty-one soil temperature-moisture plots have been established. Fourteen of these plots have been established in conjunction with the Ministry of Environment. These record continuous air temperature and monthly precipitation in forest sites as well as in adjacent clearings in order to determine relationships of soil temperature to forest canopy. Plots will be monitored for 3 to 4 years to standardize the data.

## SOIL MOISTURE AND TEMPERATURE INVESTIGATIONS IN THE KAMLOOPS FOREST REGION (E.P. 943) R.D. WINKLER

The objectives of this project are to characterize the soil moisture-temperature regimes of biogeoclimatic subzones found within the Kamloops Forest Region and to examine trends in soil moisture depletion and temperature change throughout the growing season.

Soil climate stations established in 1980 were discontinued since, within a subzone, latitudinal variability between sites resulted in greater moisture and temperature differences than between subzones. The sampling procedure was subsequently redesigned, and during the 1982 field season, one or more transects will be selected in the Kamloops area in conjunction with Air Studies Branch, Ministry of Environment.

## RANGE RESEARCH

### RANGE FERTILIZATION (E.P. 861) B. WIKEEM

In cooperation with the B.C. Cattlemen's Association, Agriculture Canada, the Ministry of Agriculture and Food, the Ministry of Environment, and Range Management Branch, the Range Fertilization Project comprises five concurrent studies aimed at evaluating the biological and economic effects of fertilizing both grassland and forested range. The five studies are:

Date of Fertilizer Trial (E.P. 861.01)

The objectives of this study are to assess the effects of 1) different application dates, and 2) the effects on forage production of pre-clipping plots in autumn to remove old growth. Forest grade urea was applied at 100 kg N/ha at 5 week intervals from October 1980 to March 1981. Plots were clipped in May and August 1981 to simulate range readiness and maximum herbage production, respectively.

Preliminary results of the study indicate the following: 1) forage production on plots fertilized in December was significantly greater than those fertilized at the other four sampling periods, and 2) plots pre-clipped in October 1980 to remove old growth produced significantly less forage than unclipped control plots.

Commercial Aerial Application of Urea (E.P. 861.02)

The objectives of this study are: 1) to demonstrate the feasibility of rangeland fertilization to beef producers and resource agency personnel, and 2) to determine the biological and economic response of range vegetation to large scale aerial fertilization.

A total of 127 t of urea was aerially applied (Plate 7) to 450 ha ofrangeland by Conair Aviation during September 1981. Application was distributed among five sites: one grassland and two clearcuts (IDF) in the Cariboo Forest Region, and two grassland sites in the Kamloops Forest Region. Grassland sites were fertilized at 100 kg N/ha and clearcuts at 200 kg N/ha. Forage quality and production, soil nitrogen and soil moisture will be monitored on both the fertilized and an adjacent control area over the next 3 years.

Plate 7. A total of 127 t of urea was aerially applied during September by Conair Aviation as part of EP 861.02.

### Rate of Fertilizer Trial (E.P. 861.03)

The objective of this trial is to test the effect of different rates of nitrogen, phosphorus and sulfur on forage production and quality. Five, three and two rates of N, P, and S, respectively, were hand applied, alone and in combination, during September and October 1981 on four sites: two grassland and two clearcuts. Forage production and quality, soil nitrogen, soil moisture and weather will be monitored over the next 3 years.

### Type of Fertilizer Trial (E.P. 861.04)

The objective of this experiment is to test the effects of different kinds of nitrogenous fertilizers on forage production and quality. Urea, urea-sulfur, ammonium nitrate and ammonium sulfate were hand applied in September and October 1981. Application rates for nitrogen simulated the aerial rates on both grassland and clearcut sites as above. Forage production and quality, soil moisture and weather data will be collected over the next 3 years.

### Assessment of Range Fertilization Using Large Scale 35 mm Color Aerial Photographs (E.P. 861.05)

The objective of this project is to use aerial photographs to produce vegetation maps for two grassland sites before and after fertilizer application. Vegetation maps produced prior to fertilization will be compared with maps produced in 1983 to evaluate the feasibility of using remote sensing to monitor vegetation changes.

Colour positive transparencies (35 mm vertical/stereo) were taken July 1981. Paper prints were produced from the transparencies. Vegetation boundaries on mylar overlays were transferred to 1:5 000 base maps using a Bausch and Lomb Transferscope. Vegetation units were interpreted and identified from the 1:8 000 aerial photographs.

Joint funding for the range fertilization project is provided by the Ministry of Forests and the Agricultural and Rural Development Subsidiary Agreement (ARDSA).

## EAST KOOTENAY PROBLEM ANALYSIS. THE INTERACTIONS AMONG GRASS, TREES, ELK AND CATTLE (E.P. 936) M.D. PITT

The objectives of the problem analysis were to: 1) provide a thorough analysis and review of the current conflicts among forestry, livestock and wildlife interests, and 2) recommend specific study areas and research programs to alleviate these management conflicts, with particular reference to the interactions between cattle and elk on private and Crown land.

Most of the current conflicts stem from philosophical and technical disagreement over proper allocation and utilization of forage. These disagreements occur primarily on low elevation Crown land, and have become increasingly pronounced by reductions in forage availability due to natural regeneration and succession. Additionally, localized problems of homesteader elk utilizing haystacks and hayfields occur on private land.

Since 1975, the Coordinated Resources Management Planning process has facilitated an increase in available forage production. Grazing management systems have been designed to benefit both livestock and wildlife, particularly elk. Disagreements exist over the proper application of these grazing systems, particularly in terms of: 1) timing of spring and fall livestock grazing, 2) the amount of forage that must be left for winter use by elk, and 3) the intensity of cattle grazing that constitutes safe use relative to plant vigour.

A research program was initiated to determine the impacts of cattle grazing on forage quality and quantity. This research will determine primarily: 1) safe levels of forage use by cattle, and 2) optimal timing of cattle grazing to increase forage quality for wintering elk.

## WILDLIFE HABITAT RESEARCH

### HABITAT RELATIONSHIPS OF MULE DEER IN THE INTERIOR DOUGLAS FIR ZONE OF CENTRAL BRITISH COLUMBIA (E.P. 903) H.M. ARMLEDER

Mule deer habitat relationships are being investigated in an effort to determine the effects of forest managment on the mule deer resource and develop means of integrating forest and wildlife management.

A comprehensive working plan covering all aspects of the research was produced and reviewed by the newly established Interior Mule Deer - Timber Research Committee. Many aspects of the project were established on the three study areas including: 1 000 long term pellet-group sampling plots, 14 micro-climatic stations and numerous track transects. Additionally, 15 mule deer were captured and fitted with radio-transmitters. Habitat use and movement data are being obtained from these animals.

### ROOSEVELT ELK - INTENSIVE FORESTRY INTERACTIONS (E.P. 912) D.W. JANZ

The major objective of this project, initiated under the Integrated Wildlife - Intensive Forestry Research (IWIFR) program, is to assess the response of elk habitat and numbers to various silvicultural treatments.

Research on elk ecology and intensive forestry interaction is required to provide the biological information necessary for effective integrated resource management.

First-year activities were related to the establishment of baseline data on seasonal movement, home range, habitat and forage utilization, animal condition and general cover type descriptions of the study area (Sayward Provincial Forest and adjacent TFL 7). Based on this information, delineation of specific home ranges and cover types for intensive monitoring of animal habitat use, activity patterns and response to experimental and operational habitat manipulation will be possible. The impact of predation on elk was also assessed. Wolf diet composition over the summer period indicates that elk contribute a major portion of prey biomass. Effects of predation on habitat selection are unknown.

Elk project staff were also involved with other IWIFR projects. A conceptual model of habitat selection, developed with Environmental and Social Systems Analysts (ESSA) personnel for use on a microcomputer, will assist in directing research activities. The model will be refined as empirical data are collected and analyzed.

### LANDSAT IMAGE CLASSIFICATION SYSTEM AS A WILDLIFE HABITAT CLASSIFICATION SYSTEM (E.P. 913) K. SADOWAY

Three Landsat image classification methods were compared as part of the IWIFR program on Vancouver Island. Each Landsat image format (paper print, positive transparency, digital computer tape) was used to develop a cover type classification map. A comparative evaluation of costs, accuracy, precision and utility of the classification system with respect to wildlife habitat application was conducted.

At present, the three Landsat classification maps and their reports have been completed. The comparative evaluation is currently underway.

### DEVELOPING A WILDLIFE-HABITAT MANAGEMENT SYSTEM (MANATAT) (E.P. 914)
K. SCOULLAR

Wildlife research programs continue to gather wildlife-habitat data needed by wildlife managers to understand the effects of forest management activities on the availability of habitat for wildlife species such as deer and elk. The wildlife managers now face the problem of applying these data to determine the habitat situation over large areas of land, and of predicting future changes in habitat availability with plant growth and proposed forest management plans. This project is part of the IWIFR program on Vancouver Island.

The objective of this research is to develop a set of computer programs (MANATAT) which will handle the complexity of these tasks using existing land maps and wildlife data, with the flexibility of using maps and data yet to be produced. A working plan has been completed.

## EFFECTS OF INTENSIVE FOREST MANAGEMENT ON NON-UNGULATE WILDLIFE (E.P. 916)

K. SADOWAY

The objective of the problem analysis was to define research questions and priorities regarding habitat needs of non-ungulate wildlife on Vancouver Island and the effects of intensive forest management on these species as part of the IWIFR program.

The problem analysis has been divided into three sections, amphibians and reptiles, mammals, and birds. Each section includes a problem reference, species habitat/life history information, wildlife-forestry interaction information and recommended research topics designed to address information gaps.

## FOREST ECOSYSTEM CLASSIFICATION AND MAPPING FOR WILDLIFE INTERPRETATIONS (E.P. 917) S. STEVENSON

The objectives of the problem analysis were to: 1) determine the needs of forest wildlife researchers and managers that could be met by an ecosystem classification, 2) describe existing classification systems, and 3) assess how well they meet those needs. The needs that were identified as desirable in a classification system included general characteristics such as adaptability and specific habitat attributes including forage abundance. The classification systems that were described were the ecosystem classification program of the Ministry of Forests, the biophysical classification program of the Terrestrial Studies Branch, Ministry of Environment, and the soil-vegetation classification developed by Moon and Selby of Agriculture Canada. Many of the criteria proposed for evaluating classification systems require field studies. An evaluation of classification systems in terms of objectives that are more general than those of the IWIFR program was recommended.

## DEER HABITAT RESPONSES TO INTENSIVE FOREST MANAGEMENT IN THE SAYWARD PROVINCIAL FOREST (E.P. 930.04) B. NYBERG

This study is designed to project changes in deer habitat values with intensive forest management in the Sayward Forest near Campbell River, based on deer habitat criteria developed on Vancouver Island and elsewhere. During

1981/82, 35 sites representing 9 ecosystem associations and 7 seral stages were sampled. At each site, understory and overstory vegetation was assessed in order to evaluate hiding cover, thermal cover, forage production and winter range values. In addition, 120 red huckleberry (Vaccinium parvifolium) plants, an important deer food, were collected in order to develop predictive equations relating basal diameter and height to plant biomass and annual growth.

## INTENSIVE FORESTRY EFFECTS ON VANCOUVER ISLAND DEER AND ELK HABITATS (E.P. 934) B. NYBERG

A problem analysis with recommendations for research topics and study areas was completed. Working plans are being prepared for studies of forage and snowpack responses to intensive silviculture practices. Thinning and fertilization experiments, being conducted by government, forest companies, and universities, are being surveyed to determine their suitability for investigations of deer and elk habitat values. This project is part of the IWIFR program.

## DEER-SNOW-TREES: A LITERATURE REVIEW AND QUANTITATIVE SYNTHESIS (E.P. 934.01) F.L. BUNNELL

The object of this project was to gather, annotate, and synthesize the literature relevant to interactions between trees and snow, and between snow and animals. The snow literature is characterized by being widely dispersed in journals of several disciplines and by being directly relevant primarily to particular hydrological, meteorological, ecological or forestry concerns. A key to this literature is badly needed to facilitate current research on production of winter range in managed stands.

Two key-worded, cross-indexed, annotated bibliographies have been completed. The first, "Annotated bibliography of wildlife:snow relationships", contains 130 entries. The second, "The effects of forests on snow cover: An annotated bibliography", contains 190 entries. Both will be updated as required.

As one approach toward synthesis of published material, the development of a complete simulation model was initiated. This model predicts snow conditions at any coastal site based on precipitation and temperature data from the nearest weather station. It utilizes snowfall and canopy cover to predict snow accumulation, and uses radiation and temperature to predict snowmelt. At the present stage of development, the model predicts snowpacks accurately only when mid-winter snowmelt is not a dominant factor. Further refinement is necessary to produce a broadly applicable model of snowpack evolution and deer use of winter range. The current state of the model is described in the report titled "STUF - A simulation of snow, trees, ungulates, and forage: Interim report". This project is part of the IWIFR program.

## EFFECTS OF WOLF PREDATION ON UNGULATES IN SECOND GROWTH FORESTS (E.P. 937)

I.W. HATTER

Recent studies in mature timber and regenerating cutover areas on northern Vancouver Island have indicated that ungulate responses to forestry practices could be masked by intensive wolf predation. Deer and elk studies initiated by the IWIFR program are examining the effects of silvicultural treatments on habitat utilization, seasonal movement and population dynamics of ungulates. The potential of wolf predation to confound these research findings appears high.

A problem analysis was initiated to provide a comprehensive perspective on the predation problem. The general effects and influences of wolf predation on ungulate populations are reviewed and contrasted to the Vancouver Island situation. The contribution of black bears and cougars as additional mortality agents is also outlined. The present unknowns and potential problems of wolf predation in second growth forest management are listed and recommendations for future research are made.

A final report, "Problem Analysis - Wolf Ecology and Predator-Prey Relationships on Vancouver Island", is being prepared.

## CARIBOU-FORESTRY INTERACTIONS IN BRITISH COLUMBIA (E.P. 939)

D.F. HATLER AND S.K. STEVENSON

This project constitutes a review of caribou distribution, population status and general biology in relation to forestry practices, past and projected, over roughly the southern half of the province. The ultimate objective, following this review, is a design of a broad-based long term research program to better describe the inherent conflict in attempting to produce both wood and a "climax forest" wildlife species (i.e. caribou) in the same area.

Review of published literature, examination of unpublished data in Provincial Government files, and interviews with wildlife and forest managers in those administrative regions where caribou-forestry interactions occur have provided the main body of information to identify the questions, pertinent techniques and most favorable study situations to be addressed in the developing research plan.

# FISH/FORESTRY INTERACTION RESEARCH

## FISH/FORESTRY INTERACTIONS IN AREAS OF INTENSIVE MASS-WASTING (E.P. 862)
V.A. POULIN

The Fish/Forestry Interaction Program was initiated in 1981 by the B.C. Ministry of Forests, B.C. Ministry of Environment and Canada Department of Fisheries and Oceans in a cooperative effort to resolve conflicts concerning steep-slope logging and integrated management of fisheries and forest resources on the Queen Charlotte Islands. The overall objectives of the program are to; 1) elucidate harvest impacts on fisheries habitat and forest sites, 2) minimize logging-induced slope instability through the use of alternate logging methods and silviculture, and 3) mitigate damage caused by landslides using stream and forest site rehabilitation techniques.

The program consists of four integrated research components which are being carried out in phases over the next 4-year period. These components are closely integrated into two broad categories: 1) synoptic studies, documenting the fish habitat damage and loss in forest site productivity due to soil mass movements and 2) prescriptive studies, assessing the suitability of alternative techniques for reducing slope instability due to logging and rehabilitation of stream and forest sites following damage by landslides. Field research commenced in June 1981 to provide a data base for evaluating alternative research strategies, developing a stratification methodology for extrapolation of study results and determining the site descriptors required to assess impacts.

## SYNOPTIC SURVEY OF WATERSHEDS (E.P. 862.02) V.A. POULIN

The objective of this component is to assess the impact of landslides on stream channel morphology, fisheries habitat and forest sites. Field research is being carried out in a wide range of representative watersheds to determine the extent and severity of landslide impacts and to permit extrapolation of study findings to unsampled basins and similar coastal environments in British Columbia. The study design described as "synoptic surveys", combines post-treatment type studies in representative watersheds with more detailed field studies in selected areas to examine special impacts and physical processes. This approach optimizes the research team's ability to detect the range of landslide impacts over a large geographical area and in the relatively short period available for study. Three projects were initiated in 1981:

1. Stratification of Queen Charlotte Islands Watersheds;
2. Fisheries Investigations; and
3. Forest Growth Investigations.

## Stratification Of Queen Charlotte Island Watersheds T.W. CHAMBERLIN

A two-stage classification approach from a high level regional stratification to fundamental landscape units was developed. This was to ensure that representative basin and stream reach types could be sampled in the synoptic surveys, and research findings extrapolated to unsampled basins. The first stage involved stratification of watersheds based on high level properties including geology, physiographic region, biogeoclimatic zone and climate. The first level of stratification identified 9 major units. Within these units, landscape units that characterize hillslopes and streams on the basis of sediment transfer potential and the manner in which landslide debris enters the stream channel were selected for detailed study in 1982/83.

## Synoptic Fisheries Studies T. HARDING

The 1981 fisheries investigations encompassed three component studies, all of which related to the linkage between fisheries habitat damage and soil mass movement. Habitat and physical channel measurements were made on 25 drainages throughout the Queen Charlotte Islands, comparing channels damaged by debris torrents to channels of similar slope, cross section and drainage area which had not been subjected to mass wasting. Results suggest that major reductions in the quantity and quality of fish habitat does occur in torrent-damaged channels.

Fish sampling was carried out at many of the study sites to relate habitat quality to degree of fish use. Results showed overall reductions in fish abundance at sites where torrents occurred. Additional work is planned in 1982 to verify these results and to further quantify the amount of productive habitat lost by other types of mass soil movements.

A study of spawning gravel quality was initiated to examine the concentrations of fines present in anadromous fish streams subjected to mass wasting. Field work was carried out during the spawning period to describe changes in the degree of sedimentation occurring in gravels from the time of salmon egg deposition to fry emergence. Analysis of the gravel data will not be complete until summer 1982. Other studies to assess spawning gravel quality included artificial placement of fertilized eggs in streams to assess egg to pre-emergent fry survival, and scour studies to determine gravel stability during winter freshets. The impact of a January 1982 debris torrent in Bonanza Creek is being monitored to determine storage time of deposited sediments. Preliminary results will be available in summer 1982.

## Slide Revegetation And Forest Growth D. SMITH

The objective of the 1981 field work was to determine the rate and pattern of vegetative succession on mass-wasted slopes as compared with adjacent non-slide terrain. Specific measures were taken to determine whether slides affect the stocking levels, composition and growth rates of tree regeneration. Browse utilization assessments were conducted to determine the effect of deer on vegetation.

Twenty landslides, aged from 1 to 70 years, were examined. Methods included running cross-slide and point-transects in the slide and non-slide areas. At each point, details were recorded on soil and humus depths, slash and natural log cover, slope and aspect, moisture regime and relief. Vegetation plots were used in the assessment. Plant species were recorded and their coverage, distribution, height and browse utilization evaluated. Trees were counted and sampled for age determination and annual height-growth increments. Soil pits were dug to determine depth and productive capability.

Seventeen of the slides sampled were classified as debris avalanches, slides and slumps and three as debris torrents. Over 90% of the surface of young (3-year old) slides were devoid of an organic layer, 60% at 7 years and less than 20% at 55 years. Extrapolation of these data indicates parity with non-slide areas at about 70-80 years. Organic mat thickness increased with time on slide surface from 22% over 10 cm thick in the youngest group to 38% at 55 years. Parity with non-slide terrain would not be expected for at least 150 years. Trends of vegetative succession appear to be strongly influenced by bedrock type, degree of erosion on the landslide, proximity to seed source, and position on the slide. Preliminary examination of the data suggests that on the Kunga formation, alder colonization occurs within the first year in the accumulation zone. Revegetation and succession occurs relatively quickly to a forest dominated by alder with relatively productive spruce in the understory. Hemlock is more prevalent in the upper portions of the slides. In contrast, slides occurring on volcanic formations such as Karmutsen and Yakoun show much slower rates of regeneration. Slides within the Honna Conglomerate Formation show an interesting pattern of succession in which alder does not play a significant role in the establishment of a pioneer community.

## STREAM AND FOREST REHABILITATION (E.P. 862.03) V.A. POULIN

Loss of soil strength due to clearcut logging is one of the major factors influencing the occurrence of landslides. Even in the most careful forest harvesting operations loss of soil strength due to removal of the forest canopy will result in decreased soil stability and landslides in steep, marginally stable terrain. This component recognizes the need to develop and apply existing methods for stream and forest restoration to mitigate landslide damage and subsequent erosion. A problem analysis on stream rehabilitation was initiated in 1981. Forest rehabilitation studies were delayed until the 1982/83.

### Queen Charlotte Stream Rehabilitation Studies - A Review Of Techniques And A Proposed Program For 1982 D. BUSTARD

Considerable experience with stream rehabilitation has been acquired in eastern North America during the past 50 years. However, in the Pacific Northwest rehabilitation of streams has met with varying degrees of success. To take advantage of experience gained elsewhere, the first phase of the stream rehabilitation studies was to review past efforts in the Pacific Northwest Region and to comment on the applicability of existing techniques most suitable for use on Queen Charlotte Island streams. A variety of potential techniques were identified and ranked for rehabilitating Queen Charlotte Island streams. The use of gabion and log sill structures offer an attractive means of improving spawning gravel stability in areas where natural stabilizing features have been lost. The development of stable side channel areas for spawners holds promise as a means of spawning stock rehabilitation in situations where suitable sites can be identified. A variety of other techniques hold promise for rehabilitation of rearing areas. The use of in-stream structures such as boulders, log sills and gabions can improve habitat diversity and potentially restore pool area. Off-channel developments such as side channel and pond rearing areas were identified as key compensatory techniques for streams where instream restoration is not possible.

## ALTERNATIVE LOGGING STUDIES (E.P. 862.05) M. NAGY AND T. SANDER (FERIC)

This study is being undertaken to develop guidelines and recommendations for reducing the risk of logging induced landslides on steep hillsides on the Queen Charlotte Islands. The study is being carried out as three projects. The first entails an appraisal of past logging methods and settings to determine where specific harvesting and environmental conflicts occur. Two settings were examined in 1981 and additional settings will be studied in 1982/83. The second involves an examination of logging planning practices currently in use. The aim of the project is to identify the limitations of existing planning methods and to develop more sensitive tools for reducing landslide risk. Three areas were selected in 1981 and will be used to demonstrate how various logging layouts can be designed to best reduce landslide problems before they occur. Relative costs are being calculated for each alternative. Finally, case studies are being undertaken to determine the limitations of various logging systems, associated site disturbance, productivity and costs. Experiments using full suspension methods including skylines and helicopters are planned. Two yarding methods were examined in 1981.

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## ACTIVE EXPERIMENTAL PROJECTS

| | | |
|---|---|---|
| E.P. 749 | MacMillan Park Study | K. Klinka |
| E.P. 782 | Soil stability on the Queen Charlotte Islands | D.J. Wilford |
| E.P. 793 | Ecosystems of the coast-interior ecotone in southwestern British Columbia | K. Klinka |
| E.P. 822 | Ecosystem classification program | R.M. Annas<br>A. Nicholson |
| | Classification of humus forms in ecosystems in B.C. | K. Klinka<br>R.N. Green<br>R.L. Trowbridge<br>L.E. Lowe |

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|---|---|---|
| E.P. 822.01 | Ecosystem classification in the Vancouver Forest Region | F. Nuszdorfer |
| | Characterization of the most productive sites for growth of coastal Douglas fir in southwestern B.C. | K. Klinka<br>M.C. Feller<br>L.E. Lowe |
| E.P. 822.02 | Ecosystem classification in the Nelson Forest Region | G. Still<br>M.V. Ketcheson |
| E.P. 822.03 | Ecosystem classification in the Kamloops Forest Region | W.R. Mitchell |
| E.P. 822.04 | Ecosystem classification in the Cariboo Forest Region | W.J. Watt |
| E.P. 822.05 | Ecosystem classification in the Prince Rupert Forest Region | J.J. Pojar |
| E.P. 822.06 | Ecosystem classification in the Prince George Forest Region | D.V. Meidinger |
| E.P. 855 | Development and evaluation of a forest water balance model for use in stand management | T.A. Black |
| E.P. 861 | Range fertilization | B. Wikeem |
| E.P. 862 | Fish/forestry interactions in areas of intensive mass-wasting | V.A. Poulin |
| E.P. 868 | Ecological investigations of wildfires in northern B.C. | D.V. Meidinger<br>J.J. Pojar<br>R.L. Trowbridge |
| E.P. 881 | The effect of fertilizers on selected ecosystems in the CDF and CWH biogeoclimatic zones | J. Otchere-Boateng |
| E.P. 882 | Classification and management of Chilcotin wet meadows | A.C. Mayall |
| E.P. 883 | Wetland classification Cariboo-Chilcotin | C.E. Jones |
| E.P. 887 | A biological study of the dry south-central region of B.C. | T.T. McIntosh |

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|---|---|---|
| E.P. 888 | Ecological description and classification of grasslands | T. Lester |
| E.P. 892 | A problem analysis of forest climatology in B.C. | W.R. Rouse |
| E.P. 902 | Soil water regimes on a forested slope | D.G. Giles |
| E.P. 903 | Habitat relationships of mule-deer in the Interior Douglas Fir Zone of central British Columbia | H.M. Armleder |
| E.P. 905 | The simulation of Landsat-D and an assessment of its capabilities for the inventory and assessment of wetlands for management purposes | G.F. Tomlins |
| E.P. 912 | Roosevelt elk - intensive forestry interactions | D.W. Janz |
| E.P. 913 | Landsat image classification as a wildlife habitat classification system | K. Sadoway |
| E.P. 914 | Developing a wildlife - habitat management system (MANATAT) | K. Scoullar |
| E.P. 915 | An adaptive systems approach for the research program on integrated wildlife-intensive forestry on Vancouver Island | D. Eastman |
| E.P. 916 | Effects of intensive forest management on non-ungulate wildlife | K. Sadoway |
| E.P. 920 | Investigations of soil temperature in ecosystems of the Prince Rupert Forest Region | R.L. Trowbridge<br>K. McKeown |
| E.P. 930 | An ecosystematic approach to silvicultural management of immature forests - Sayward Forest Study | R.N. Green<br>J.B. Nyberg |
| E.P. 931 | A problem analysis of grassland classification | A. Nicholson |
| E.P. 934 | Intensive forestry effects on Vancouver Island deer and elk habitats | J.B. Nyberg |

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|---|---|---|
| E.P. 936 | Problem Analysis: Interactions Among Forestry, Range and Wildlife Management in the East Kootenays | M.D. Pitt |
| E.P. 937 | Effects of wolf predation on ungulates in second growth forests | I.W. Hatter |
| E.P. 939 | Caribou-forestry interactions in B.C. | D.F. Hatler<br>S.K. Stevenson |
| E.P. 942 | Ecosystem Association Mapping in the Truax Basin of the Kamloops Forest Region | W.R. Mitchell<br>R.D. Winkler |
| E.P. 943 | Soil moisture and temperature investigations in the Kamloops Forest Region | R.D. Winkler |
| E.P. 947 | Investigations of atmospheric and soil climate in the Dome Creek - McBride - Valemount Area of the Rocky Mountain Trench | W. Blashill<br>G.D. Hope<br>A.J. McLeod |

## BIOMETRICS AND DATA PROCESSING SERVICES

1981/82 brought major improvements in regional computing capabilities. Video display terminals coupled with a screen image printer have been installed at all regional headquarters and at Red Rock Research Station. With the exception of Kamloops Forest Region, a high speed printer is also available to print large volumes of output. These facilities communicate directly with the Victoria-based computer system, providing access to a variety of programs and data bases. Regional researchers can now store, retrieve, edit and analyse their data directly.

The variety of activities and assistance provided by the biometrician reflects the growing emphasis on biometrics in the branch. The staff biometrician reviewed about 20 working plans, helped to analyse data from approximately 80 experimental projects and consulted on statistical matters. Frequent consultation was provided on the use of the Statistical Analysis System (SAS) package and interactive programs were written to assist researchers in its application. Lectures were prepared on experimental design and the use of SAS for presentation to the regional researchers.

Systems activities centered around:

- development and upgrading of systems and programs,
- the training of research staff, and
- technical support for research staff.

Development and upgrading work on the various programs and packages made computerized procedures more accessible to researchers. The operation of these programs requires little or no computer knowledge. They cover a wide variety of applications, including data control, file security and routine computations needed in the ecology and silviculture research.

Regional research personnel were trained in the use of the IBM 3278 video display terminals, the WYLBUR sub-system and the use of some computer programs relevant to their work. As a result of this training, turn-around time for minor analyses is expected to decline.

With more computer access, there has been an increase in technical support requested by researchers. This support covers a variety of data processing problems (data editing, input format design, interpretation of output) as well as assistance in the use of statistical packages, system utilities and subroutines.

Approximately 350 new data sets have been added to the data library, giving a total of 813 (746 876 - 80 character records). Individual documentation is stored with each data set.

The tree breeding map masterfile has increased in size to 77 plots for a total of 200 000 - 80 character records. Data control has provided computerized maps for the field crews along with summaries for these data.

Biometrics seminars sponsored by the Research Branch have proven popular among personnel in forestry and other natural resource disciplines. The seminars were held monthly and attracted a wide cross section of people from provincial and federal ministries, as well as universities and the forest industry. Speakers from various organizations addressed a wide range of current topics including:

1. Simulated silvicultural experiments
2. Whole forest models
3. Multivariate analysis
4. Managed stand monitoring vs research installations.

A new series of biometrics seminars is being scheduled for the forthcoming year to satisfy continuing interest.

## ANALYSIS OF THE 1977-81 "PLANTING HAZARD INDEX" - E.P. 766 DATA H.B. STAUFFER AND V.E. FLETCHER

E.P. 766 addresses the problem of constructing a planting hazard index expressing percentage of seedling survival as a function of site, seedling, and weather variables. Coastal Douglas fir seedlings, evaluated initially for uniform quality by seedling quality tests (i.e., root growth capacity (RGC), bud development (BD), moisture potential (MP), and nursery seedling quality tests), have been planted at various elevations in the Vancouver Forest Region on six separate dates at 2-week intervals throughout the summers of 1977-79. Additional seedlings have also been planted operationally at various elevations and sampled on three separate dates at approximately 2-week intervals during the summers of 1980 and 1981.

The following factors affecting seedling survival are being considered:

1. site qualities such as aspect, biogeoclimatic zone, soil horizon, soil potential, soil analysis (N, pH);

2. seedling qualities such as seedling potential ("seedling moisture stress"), wilting percent, species, stock type, seedlot (provenance), cold storage period, exposure to air prior to planting, seedling quality;

3. weather conditions (at time of planting) such as temperature (present, maximum, minimum, and 10 cm above ground), soil temperature (10, 20, and 30 cm below the surface), precipitation, relative humidity, soil moisture, evaporation, wind velocity, wind direction, buildup index (BUI), date of planting; and

4. others such as planting crews and subsequent weather conditions.

Data have been collected for many of these variables.

Up to eight assessments of seedling survival and quality (good, fair, or poor) were taken at 2-week intervals following the planting.

Analyses (using multiple regression techniques such as stepwise regression and principal components regression) were inconclusive due to incomplete data sets and the limited scope of the experiment. Insufficient data had been collected to represent an adequate range of relevant values for the most important site, seedling and weather variables affecting seedling survival. However, preliminary results indicate that factors such as soil temperature and soil moisture content are important determinants of survival. Not surprisingly, BUI (a component of the fire weather index) also showed promise as a predictor of survival since it incorporates measurements of air temperature, relative humidity and precipitation. Localized site conditions and seedlot type are important to a lesser extent. An important aspect of the data is the inter-relatedness (high correlation) of many of the weather variables. This makes interpretation of results difficult but suggests the practical possibility of using the more easily measured variables as the basis for a planting hazard index.

## STATISTICAL GUIDELINES FOR MULTIPHASE SAMPLING H.B. STAUFFER AND V.E. FLETCHER

Computer programs have been developed to supply sampling guidelines and calculate statistics for multiphase (double) sampling. These programs are currently being utilized by Inventory Branch for their Inventory Multiphase Sampling System which employs photo (primary or phase 1) and ground (secondary or phase 2) samples. Potential application is also anticipated for range sampling in Range Management Branch and for pest surveys in Protection Branch.

These computer programs have been implemented on the BCSC IBM system using VSPC and are available upon request.

## EXAMINATION OF ERROR ANGLES IN THE PROTECTION BRANCH LIGHTNING LOCATION SYSTEM H.B. STAUFFER

In cooperation with Protection Branch, computer programs have been developed to examine error angles which have been associated with the detection of strikes in the Lightning Location System. Detection devices have been located in the B.C. interior which can detect the direction of lightning strikes within the limits of an unknown error. The position of lightning strikes can be precisely determined once these error angles are known.

Using certain simplifying assumptions, several computer programs have been developed to examine more closely the extent of these error angles. One computer program calculates the position and area of a polygonal region within which the lightning strike will have occurred. A second program uses an iterative technique on data to reduce the possible ranges of these error angles for each detection device and all directions. It is hoped that, with the addition of a large amount of data from storms next summer, this second program should reveal much information about the values of these error angles for detection devices throughout the province.

With better knowledge of the site errors, each detection device can be adjusted to automatically correct for known errors thus improving the accuracy of the system.

## ANALYTICAL AND COMPUTATIONAL ASPECTS OF THE ECOLOGY PROGRAM R. GITTINS

The primary objective of the investigation is to identify ways in which the Biometrics and Systems Section could offer increased support to the Ecology Program. Attention has focussed on two aspects, namely 1) the conceptual framework underlying the vegetation survey and its properties, and 2) the computational needs of the program.

The conceptual framework which has guided and shaped the vegetation survey since its inception is that of the European phytosociological tradition. Two distinctive properties of the approach are 1) the selective nature of the sampling design used, and 2) the lack of incisiveness of its analytical procedures. It seems that the constraints imposed by these features are not as widely recognized as they deserve to be. In the long term, the introduction of computer programs designed to implement a variety of algebraic methods of use in vegetation survey may well be advantageous. Attention is therefore being drawn to opportunities which alternative sampling schemes and a more strictly analytical approach offer in relation to realization of the program's goals.

Ways in which the Section might contribute more effectively to provenance and wildlife research have also been explored. Considerable scope for the application of multivariate statistical methods exists in both areas.

## CALIBRATION OF THE TASS GROWTH MODEL FOR LODGEPOLE PINE (E.P. 850.01)
J.W. GOUDIE AND K.J. MITCHELL

The Tree and Stand Simulator (TASS II) was modified and calibrated to conform with Research Branch permanent sample plots and data provided by the Canadian Forestry Service, Alberta Forest Service and industry. The model produced managed stand yield tables in which establishment density is the primary management variable. Juvenile spacing is currently being incorporated in cooperation with the Alberta Forest Service.

### RECALIBRATION OF THE TREE AND STAND SIMULATOR (TASS II) FOR COASTAL DOUGLAS FIR (E.P. 927) K.J. MITCHELL

Permanent sample plots from B.C., Pacific Northwest, New Zealand and France are being assembled and analysed as part of a continuing recalibration process. Components dealing with height growth, mortality, fertilizer response, and merchantability specifications were upgraded. An economic analysis system was completed and should be operational in 1982.

The model was employed to assess the impact of various management variables on yield, including establishment density and spatial distribution (Slash Burning - Ecology Workshop), juvenile spacing (Western Forestry Conference), fertilization and commercial thinning. The last three regimes were incorporated into scenarios designed to examine the impact of intensive silviculture in the Fraser TSA. Growth and yield requests from industry and other branches were also fulfilled. Approximately 20 simulated experiments produced by TASS were organized into an educational program for Stand Tending Coordinators and other groups.

The development of managed stand yield tables is in progress for plantations of Douglas fir established at various densities and subjected to different juvenile spacing regimes.

## PUBLICATIONS

Stauffer, H.B. and C.D. Nigh. 1981. Available: a computer model which simulates quadrat sampling for tree density and spacing. Forest Science 27(1):31-32.

Stauffer, H.B. 1982. A sample size table for forest sampling. In press. Forest Science.

## ACTIVE EXPERIMENTAL PROJECTS

| | | |
|---|---|---|
| E.P. 850.01 | Calibration of the TASS growth model for lodgepole pine | J.W. Goudie and K.J. Mitchell |
| E.P. 850.02 | Investigation of the causes of stagnation in lodgepole pine stands | K.J. Mitchell |
| E.P. 924 | Improved sampling methodology: sampling for tree density and spatial patterns | H.B Stauffer |
| E.P. 925 | Improved methods of sampling design | H.B. Stauffer |

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|---|---|---|
| E.P. 926 | Improved methods of experimental design | H.B. Stauffer |
| E.P. 927 | Recalibration of the tree and stand simulator (TASS II) for coastal Douglas fir | K.J. Mitchell |

## INFORMATION AND IMPLEMENTATION

With 1981 came a considerable increase in regionally sponsored publications. Consultation with regional researchers and coordination of the final preparation and printing of their publications consumed the majority of time. To this end, six Land Management Reports and four Land Management Handbooks were published. Four of the Land Management Reports were prepared in cooperation with other provincial agencies and UBC. Three of the Land Management Handbooks are plant identification guides for various areas of the province while the fourth presents plant indicators of moisture with engineering interpretations for southeastern B.C.

Forest Report was published four times during 1981/82. The newsletter continued to receive favourable feedback while the distribution was increased to near 8 000.

All experimental project file reports were catalogued according to author, project title, keywords, E.P. number, and report type. These data were entered into the Quick Law (Q.L.) computerized library catalogue and are available for researcher use through the Ministry of Forests Resource Centre in Victoria.

Discussions were initiated with regional research staff to investigate the possibility of including headquarters project results in regional training packages.

## ACTIVE EXPERIMENTAL PROJECTS

| | | |
|---|---|---|
| E.P. 854 | An evaluation of the information function of Research Branch. | T.D. Mock |

# OPERATIONAL RESEARCH IN THE MINISTRY OF FORESTS

## INVENTORY BRANCH

### Growth and Yield Study in Managed Forest Stands

Of the 85 installations of permanent growth plots established in coastal Douglas fir and western hemlock, mostly on Vancouver Island, 33 installations comprising 346 plots were remeasured during the fall of 1981. The installations are designed to monitor the effects on growth of operational applications of juvenile spacing and fertilization. In conjunction with plot remeasurement, fixed-based large scale aerial photography was continued.

Under the auspices of the Intensive Forestry Program, 20 installations consisting of 330 permanent sample plots were established in various stands throughout the province that were juvenile spaced in 1981. These stands were located in five forest regions and averaged 52 years of age.

### Growth and Yield Study in Natural Forest Stands

In 1981, 175 permanent growth plots were remeasured in Forest Inventory Zones G, H and I (interior regions). In addition 102 experimental samples were remeasured in Forest Inventory Zones A, B and D (lower coast and interior).

### Relationship of Stand Growth and Yield and Ecosystem Classification Units

Ecosystem classification of Inventory Branch's 3 000 permanent sample plots could be useful information for analyzing growth trends on ecological units. A pilot project initiated by Inventory Branch was planned and carried out in cooperation with Research Branch and the Kamloops and Vancouver regional research sections. So far, 26 and 16 permanent sample plots were classified into ecosystem associations in these regions, respectively. The pilot project will be expanded in 1982 in the Vancouver Forest Region in order to provide a sufficient number of ecologically classified sample plots for preliminary analysis.

# SILVICULTURE BRANCH

## Site Preparation

### TRIALS WITH MARTTIINI SCARIFIER PLOW (SX 81512Q)

Trials were undertaken to determine the suitability of the Marttiini Scarifier Plow to prepare a relatively level lacustrine clay site with a high water table and thick moss layer for hand planting. The object was to remove the debris and moss, and to provide a relatively elevated shoulder of humus as a planting site. The machine was successful to the extent that it removed all debris, including stumps, formed a central channel and, to a great extent, preserved the thin layer of humus as a planting shoulder adjacent to the central channel. Due to the very flat nature of the site, very limited drainage is anticipated and the central channel will only be a catch basin which is unlikely to be adequate to contain excess water over the entire site.

## Nursery Development Trials

### 1+1 PLUG TRANSPLANT TRIAL (SX 81201Q)

This is a 2-year study designed to gather morphological data on transplanted interior spruce and interior fir seedlings. Several stock types are being compared including: 1 P + 1 (PSB 211 and 313), 1/2 P + 1 1/2, 1/2 P + 1, 2 + 1, 1 1/2 + 1 1/2, and 1 1/2 + 1/2. The basis for these rotations has been determined both by the nature of the requests for larger transplanted stock and the desire to produce multiple crops from greenhouse facilities. Results from the first year's testing are currently being tabulated.

### HARROP NURSERY ASSESSMENT (SX 81202Q)

Container testing at Harrop was expanded this year to look at various sowing dates to meet multiple crop rotations. In addition, previous testing of extended photoperiod, different fertilizers, fertilizer rates and warm water was continued.

One of the most important results was the exceptional quality and vigor of interior Douglas fir produced from a March 1st sowing. This treatment which was moved outside in early June yielded root weights exceeding 0.70 g. Conversely, the replacement crop grown entirely in the greenhouse was inadequate for outplanting and barely acceptable for transplanting.

Normal sowing dates (April 1) for both spruce and fir resulted in generally acceptable crops from the greenhouse. Although tops were excessively tall under lights, they could be controlled with proper conditioning. Treatments grown in an untreated shelterhouse using Osmocote 18-6-12 (5.9 $kg/m^3$) were also quite acceptable in most seedlots. Hi-sol treated seedlings tended to be lacking in root weight.

Other species such as western hemlock exceeded optimum specifications in the heated greenhouse using Osmocote 18-6-12 at 1.3 $kg/m^3$ plus supplemental feeding with Hi-sol fertilizers. Western red cedar also was satisfactorily grown in a greenhouse or shelterhouse using the high rate of Osmocote or Hi-sols.

The best treatment for lodgepole pine was a shelterhouse start using Osmocote or Hi-sol fertilizers followed by a move outside in early July. Unlike last year, treatments grown entirely outside were lacking in root weight and only just met the minimum height specifications. All of the above results are consistent with the results of previous trials at Harrop.

## THORNHILL NURSERY ASSESSMENT (SX 81203Q)

This trial represents the first full year of testing on the proposed Thornhill nursery site.

Although results are not yet tabulated, preliminary observations have indicated this site can grow quality seedlings of interior and Sitka spruce, lodgepole pine, western hemlock, western red cedar and amabilis fir.

One notable observation came from an early sowing (March 1) of interior spruce which was transferred from the greenhouse to outside in early June. As with the interior fir at Harrop, this early rotation demonstrated exceptional top/root balance and overall quality while the replacement sowing (June 1) was not up to standard for outplanting or transplanting. More detailed analysis will be forthcoming in a later report.

## ROOTSTOCK GROWTH ASSESSMENT (SX 81204Q)

This is a 2-year trial designed primarily to assess root form in the newly designed MOF 4.5 ℓ square pot compared to the commonly used 3 ℓ round pot.

After one year's growth transplanted seedlings of interior spruce and Douglas fir in the square pot have demonstrated exceptional top growth and good root form with no root spiralling and air root pruning at the bottom. Although lodgepole pine did not put on much height increment, girth and root mass increased proportionately. The lack of top growth may have been due to a high saline buildup from the Osmocote soil mix.

Use of copper paint on the sidewalls appears to have produced lateral root pruning on both the square and round pots. In each type, root mass was sufficiently heavy enough to firmly hold the soil together when the seedlings were pulled from the pots.

Indications are that the square pot will satisfactorily meet the needs of the seed orchard grafting program. An improved version of the square pot is being tested this year with grafting to occur one year after transplanting.

## AN EVALUATION OF APPLYING CUPRIC CARBONATE TO STYROBLOCK CAVITIES (SX 81205Q)

Since research has shown that lateral root pruning of lodgepole pine can be effectively controlled by coating the cavity walls with a paint containing cupric carbonate, the next stage is to adapt this technique to production use. In this trial two such methods are being explored:

1. Impregnate the chemical into the block during the manufacturing process; and

2. Spray the chemical onto the cavity wall surfaces.

The species tested are lodgepole pine and western red cedar.

Because of late sowing, assessment has not yet been done, but initial inspection shows that the impregnated treatment is showing little evidence of lateral root pruning compared to the spray painting. Consequently, more effort is being put into mechanizing a spraying system.

## CHEMICAL ROOT PRUNING TRIAL WITH LODGEPOLE PINE (SX 81212Q)

During 1981 the chemical root pruning technique (E.P. 791) was tested operationally with lodgepole pine. A total of more than 500 styroblocks (PSB 211 or 313) were coated with latex paint containing 0.07 kg/ℓ of basic cupric carbonate powder (Plate 8). Painted blocks were used at five nurseries: Skimikin and Vernon in the Kamloops Forest Region; Harrop in the Nelson Forest Region; Red Rock in the Prince George Forest Region; and Koksilah in the Vancouver Forest Region. At Harrop and Koksilah, results were entirely satisfactory. Virtually all lateral roots were pruned and there was no apparent growth reduction due to the treatment. At Skimikin and Vernon, growth of the treated stock was close to, or identical with that of control stock and in three or four seedlots a large proportion of the first order lateral roots were pruned. The results with one seedlot at Skimikin and the single seedlot included in the trial at Red Rock were unsatisfactory. The treatment reduced growth and only a minority of the roots were pruned.

Field performance of the stock that was satisfactorily root pruned will be compared with that of untreated stock. Survival, growth rate and mechanical stability will be monitored.

Factors thought to have contributed to the failure of the chemical root pruning treatment at two nurseries include overwatering and the low pH of the growing medium. These are possibilities to be evaluated in trials conducted this year.

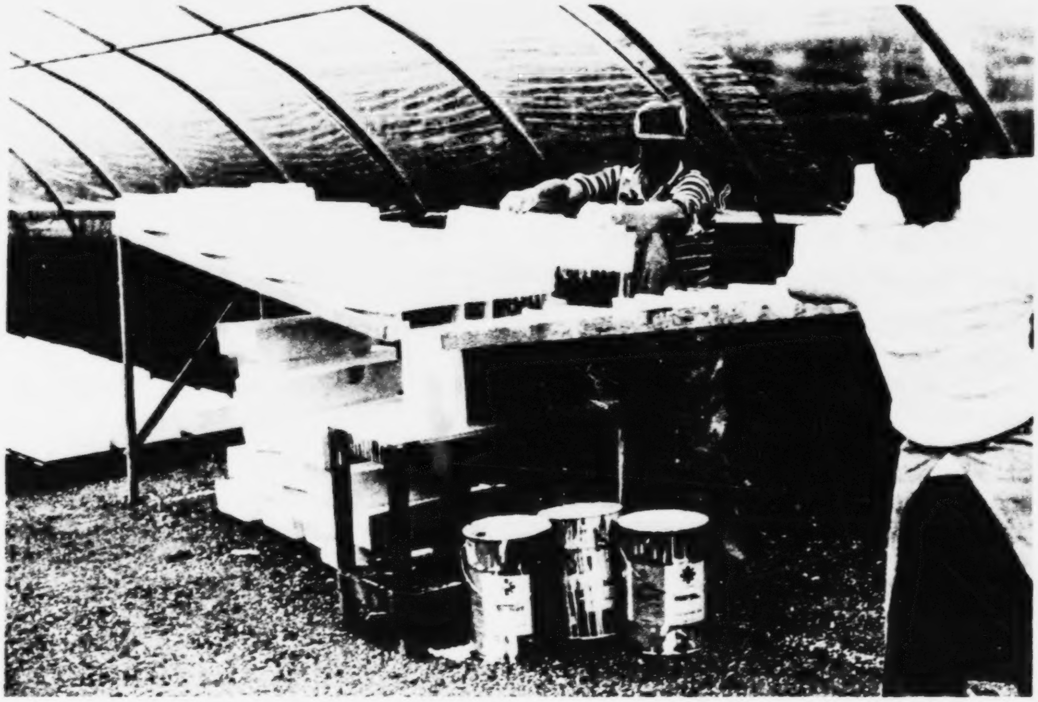

Plate 8. Dipping styroblocks in copper paint. The blocks were used in an operational scale trial of the chemical root pruning technique (SX 81212Q).

## Planting

### BULLET-PLUG TRIAL (SX 8001)

This trial was established at ten locations in six forest regions to test the relative performance of various species grown in square plastic bullets (CBW 210) with those grown as plugs (PSB 211, 313).

After two growing seasons, survival, except at one location was very satisfactory, i.e. +80%. As between the two stock types, plugs had the edge over bullets to varying degrees in terms of survival, height growth, and cost.

## HORMONE BULLET TRIAL (SX 8002)

The application of growth hormones to Douglas fir seed was inconsistent in promoting the survival and growth of this species when grown in square plastic bullets.

Of the eight available comparisons between the treated and untreated, the untreated survived better in four, the treated in three, and the same in one. Similarly, the relative performance in total height growth did not differ greatly.

## TRIAL OF PELTON GROWN MUDPACKS (SX 8003)

Lodgepole pine and interior spruce were greenhouse grown and mudpacked as 1+0 by Pelton Reforestation Ltd. Their performance, when outplanted at six interior locations, was compared with that of plugs (PSB 211).

After 2 years, the survival of both was very satisfactory and difference between the two stock types was slight. Total height growth was, however, without exception, greater for plugs than for mudpacks.

## WESTERN HEMLOCK PAPERPOT TRIAL (SX 8004)

The object was to compare the survival and growth of western hemlock grown as plugs (PSB 211) and paperpots (CPPf 408) when outplanted on the west coast of Vancouver Island. After two growing seasons, the survival of both stock types was satisfactory, i.e. in the order of 75-80%; any difference was generally in favour of the plugs. Seedlings overcame planting shock after one year and are now growing satisfactorily. The initial advantage in height that plugs had over paperpots has been maintained or slightly increased. In general it can be said that differences in performance between the two stock types have not been great but generally are in favour of plugs.

## STRUCTURE SOIL TRIAL (SX 8005)

Structure soil, a compressed cylinder of peat-perlite/vermiculite, is a growth medium intended to produce plantable seedlings in a relatively short period that are free of root deformation. When outplanted at four coastal and one interior locations, seedlings in structure soil survived well, as did the plug control (PSB 211, 313), which was superior to structure soil in all cases.

### BULLET PLANTING GUN TRIAL (SX 80101Q)

An experimental planting tool, the PAL-2 gun, developed by Engineering Branch to plant Walters' square plastic bullets, was tried on an operational planting project in the Cariboo Forest Region. Planting production with the gun was 30% greater than with the standard dibble and involved less physical effort. As was found in a previous planting gun trial (RNX 7905) results confirmed that its use should be confined to relatively stone free sites.

### STOCK TYPE DEVELOPMENT TRIAL (SX 80100Q)

In 1979/80 an extensive series of inactive stock trials was examined to assess their value as a future source of data in terms of height, diameter growth, and root form development. Of the 120 plots examined, 22 were judged suitable for retention. These have now been spaced, and tallied for diameter and height as a potential source of information on the development of various species and stock types.

## Seeding

### SPOT SEEDING TRIAL (SX 80300Q)

A second series of plots was established in spring 1981 and both the 1980 and 1981 plots were examined in the fall of 1981. First growing season results of the 1981 plots were relatively similar to those recorded last year for the 1980 plots. Results of the 1980 sowing (two growing seasons) are shown in Tables 13 and 14.

In summary, after two growing seasons:

1. Sheltercones produced more survivors on more spots than did the soil-cover or no-cover treatments.
2. Sheltercones appear to favor height growth.
3. Differences in diameter growth are not apparent.
4. Aspect appears to have no effect on germination, survival or growth.
5. Sheltercones are 90% degraded with no apparent difference noted between 4 degrees of latitude.

Plots will be re-examined in spring and fall of 1982.

Table 13. Spot seeding trial; survival after two growing seasons - all locations and sites. (first growing season comparison in brackets)

| SPECIES | SEEDSPOT COVERING | % OF SEEDSPOTS WITH ONE OR MORE GERMINANTS ("stocked") | AVERAGE NO. OF GERMINANTS PER "STOCKED" SPOT (7 seeds shown per spot) |
|---|---|---|---|
| Interior Spruce | Sheltercone | 82.0 (90.7) | 4.06 (4.42) |
| | Soil | 31.0 (63.3) | 2.33 (2.54) |
| | No cover | 2.3 (14.3) | 2.00 (1.93) |
| Lodgepole Pine | Sheltercone | 90.6 (92.2) | 4.38 (4.86) |
| | Soil | 37.9 (48.9) | 2.17 (2.35) |
| | No cover | 11.7 (14.4) | 1.33 (1.31) |
| Douglas Fir | Sheltercone | 54.2 (55.0) | 4.40 (4.77) |
| | Soil | 17.9 (20.0) | 1.60 (1.60) |
| | No cover | Negl. (2.1) | Negl. (1.20) |
| Western Larch | Sheltercone | 96.7 (98.3) | 3.72 (4.20) |
| | Soil | 28.3 (61.7) | 2.06 (2.20) |
| | No cover | 0 (1.7) | 0 (1.00) |
| Ponderosa Pine | Plots were abandoned. | | |

Table 14. Spot seeding trial; growth after two growing seasons - all locations and sites. (average of heights and diameters of largest survivor over 1 cm in height)

| SPECIES | SITE (Aspect) | SHELTERCONE COVER | | | SOIL COVER | | |
|---|---|---|---|---|---|---|---|
| | | Cases | Ht (cm) | Diam (mm) | Cases | Ht (cm) | Diam (mm) |
| Interior Spruce | Favorable | 87 | 4.19 | 0.87 | 14 | 2.65 | 0.98 |
| | Unfavorable | 35 | 2.94 | 0.79 | 6 | 1.93 | 0.73 |
| | All | 122 | 3.82 | 0.85 | 20 | 2.43 | 0.91 |
| Lodgepole Pine | Favorable | 44 | 4.64 | 1.39 | 16 | 3.40 | 1.64 |
| | Unfavorable | 61 | 4.32 | 1.38 | 19 | 3.01 | 1.40 |
| | All | 105 | 4.45 | 1.38 | 35 | 3.19 | 1.51 |
| Douglas Fir | Favorable | 19 | 3.27 | 1.11 | 7 | 2.70 | 0.86 |
| | Unfavorable | 43 | 3.54 | 1.04 | 6 | 2.69 | 1.07 |
| | All | 62 | 3.46 | 1.06 | 13 | 2.70 | 0.96 |
| Western Larch | Favorable | 7 | 8.13 | 1.69 | 5 | 5.24 | 2.02 |
| | Unfavorable | 12 | 6.73 | 1.69 | 5 | 5.84 | 1.98 |
| | All | 19 | 7.24 | 1.69 | 10 | 5.54 | 2.00 |

BRACKE SEEDING (SX 81308Q)

The objective of this trial is to evaluate the Bracke Scarifier and seeding attachment as an operational reforestation tool.

A suitable clearcut site was selected in the Kamloops Forest Region and seeding of lodgepole pine was carried out on 20 ha during the early part of November 1981. Prior trapping of the area indicated a very light rodent population. Forty seven, 50 $m^2$ sample plots were established over the treated area.

An adjacent clearcut will be trapped and seeded in the spring 1982 to provide a seasonal comparison. Sample plots on both seeded sites will be monitored during the 1982 growing season.

## Stand Tending

TESTS OF ROUNDUP AND KRENITE - NORTH THOMPSON AND KAMLOOPS REGIONS (SX 79601Q)

As reported in the Forest Research Review 1980/81, plot installations to measure the efficacy of the herbicides Roundup and Krenite were established in the wet subzone of the ESSF Biogeoclimatic Zone at Lempriere Creek. The test area, situated 30 km north of Blue River, B.C. at elevations from 1 340 m to 1 430 m was logged in 1971. Using the Solo knapsack sprayer and Micron-herbie ULV rates of 500 and 1 000 g ai/ha of Roundup (glyphosate) and 1 000 and 2 000 g ai/ha of Krenite were applied during the summer of 1979. After one year, percent cover reductions of vegetation consisting mostly of fireweed, oak fern, bracken and horsetail, patches of gooseberry, huckleberry, false azalea (brush species mostly under 2 m in height) were judged acceptable for all Roundup plots. Applications of 2 000 g ai/ha of Krenite resulted in significant cover reduction in the first year but after 2 years, cover has increased to levels above the average found in controls (1981 average cover 88.7%). On the other hand, Roundup plots are still 14.2% to 40.7% below the 1981 control average and it is likely that brush and weeds in these plots, although recovering, will not overtop presently exposed conifers for sometime, if ever.

It appears that applications of glyphosate as low as 500 g ai/ha will reduce vegetation cover significantly for at least 2 years. Vegetation treatment efficacy is enhanced by ULV application. Comparable results may be obtained with Krenite at application rates much higher than 2 000 g ai/ha, but this is not a cost effective solution based on current product costs of both herbicides.

## COAST AND INTERIOR GIRDLING TRIAL (SX 7801)

Stem girdling trials, using two versions of the North Star girdling tool, were carried out monthly at coastal and interior locations to examine the effectiveness of girdling to space juvenile stands. After 3 years, mortality in coastal Douglas fir, hemlock and interior lodgepole pine has exceeded 90% based on total (100%) browning of foliage. Trees in the 7.5 cm to 12.5 cm range are readily scored but the jaw calipers of the machines tested makes it difficult to remove bark from trees below 5 cm and almost impossible to treat trees over 15 cm. Continuous production rates of 205 stems/hr were obtained (in a lodgepole pine stand averaging about 10 cm and 9 000 stems/ha) but depending on the strength and fatigue level of the operator, higher rates are possible.

Girdling streambank alder has proven successful thus offering a safe alternative to chemical or power saw treatments within environmentally sensitive zones.

## PROTECTION BRANCH

### Fire Studies

A joint study with Silviculture Branch and the Canadian Forestry Service involving the measurement of fuel loadings and characteristics for various tree species and spacing regimes is nearing completion. Data collected for coastal and interior locations were used to construct a computer model describing the fire behaviour potential of stand spacing projects. Guidelines for project design and execution relating to fire management considerations will be issued.

Investigation into the ecology of fire in the forests of the northern Prince George and Prince Rupert Forest Regions continued in 1981, with the Cassiar and northern Mackenzie TSAs receiving field examination. The Canadian Forestry Service and Research Branch are cooperating in this study, the objectives being 1) to delineate the biogeoclimatic zones and subzones of the north, 2) to determine what the effects of forest fires have been in the forest types within these zones, and 3) to provide land managers with needed information and aids to assist in making multiple resource oriented land and fire management decisions. Reports for the Fort Nelson TSA studied in 1980 are in the final stages of preparation, while data analysis is underway for the other study areas.

Protection Branch is also participating in a national study to develop a Fire Damage and Risk Assessment System. A problem definition and study strategy are under development. In cooperation with Planning Branch the application of computer analyses to the Fort Nelson TSA has commenced as a pilot project to test the suitability of certain techniques.

### Equipment Development and Products Testing

Utilizing technology jointly developed by Lightning Location and Protection, Inc. of Tucson, Arizona and the Ministry of Forests, the lightning location network in the province is gradually expanding. Following trials in the Kamloops Forest Region in 1980 the system was enlarged slightly in 1981 and the data acquisition and processing techniques were modified to a more efficient mode.

The network currently consists of four direction finder units in the southern interior and seven more will be installed in the southwest and central portions of the province to give 75% coverage. Computer graphic output terminals at Ministry regional offices will permit users to access the data base held in the IBM computer in Victoria and thus monitor lightning activity. Knowledge of the lightning distribution will permit accurate routing and scheduling of patrol aircraft as well as influence the deployment of forest fire suppression crews.

## Forest Pest Studies

A project undertaken by Dr. John Borden of Simon Fraser University and partially funded by the Ministry of Forests indicated that prospects are good for the identification of mountain pine beetle pheromones. These compounds could be utilized in survey operations as well as for population control. A comprehensive report has been prepared, the work will continue next year.

This was the final year of a 3 year study by Dr. Peter Oloffs at Simon Fraser University into the impact of acephate (Orthene R) upon aquatic organisms. This chemical appears to be a good choice for control of defoliator insects where the aquatic environment deserves special protective measures.

The second of a potential 3-year study of the effectiveness of trap trees indicated that this treatment is useful in containing the spread of the spruce beetle. Cost-benefit parameters and biological considerations are being assessed in this analysis being done in the Prince George Forest Region. Final publication of the results is scheduled for after the termination of the 1982/83 field sampling.

A project undertaken by the Canadian Forestry Service to determine root disease survey and management strategies has been funded by the Ministry. This work is continuing from previous years and promises to yield useful survey and disease management information.

An increasing population of Douglas fir tussock moth was detected in the Hedley/Princeton area in the fall of 1980. In response, the Ministry of Forests, in cooperation with the Canadian Forestry Service, undertook an operational trial to test the efficacy of introducing a nuclear polyhedrosis virus specific to the tussock moth early in the infestation to provide control before significant damage was sustained. Early results appear to be very promising and valuable information has been obtained on efficacy and application techniques. Final publication of results is expected during the spring of 1982. The persistence of the virus will also be monitored during the 1982 field season.

Protection Branch cooperated with Kamloops Forest Region and Inventory Branch on developing methods for determining losses sustained by outbreaks of the Douglas fir tussock moth. Suitable techniques can later be adapted for use with other defoliators.

A small experiment to test the effect of water sprinkling of log decks on mountain pine beetle survival was carried out by the Canadian Forestry Service with funding from the Ministry of Forests. Soaking of log decks for several weeks caused high mortality of the beetle and this technique may prove useful in limiting the spread of beetles from decked material. A final report publication is being prepared.

A dwarf mistletoe project was undertaken and completed by Dr. John A. Muir at Selkirk College. In five forest districts dwarf mistletoe infestations were surveyed, growth losses estimated, and control treatments recommended. Tentative regional guidelines were outlined. The final report is being prepared as an internal publication.

Protection Branch cooperated with Monsanto and the Canadian Forestry Service on tests of efficacy and residue of Roundup.

## ENGINEERING BRANCH

### Biomass Project

This project is a joint Federal-Provincial study to evaluate the productivity and costs of harvesting and processing residual biomass on wet belt cedar-hemlock sites in B.C. A secondary objective is to establish the impact of reduced site rehabilitation and regeneration costs on the net costs of harvesting biomass.

### Log Haul/Road Recorder Project

The purpose of this project is to provide an accurate means of estimating truck cycle times for appraisal and transport analysis.

The road recorder is a vehicle, equipped with electronic instruments, for surveying forest roads at moderate driving speed. Survey data are collected on magnetic tapes. The software system includes programs to produce a plan and profile of each road, or any combination of roads.

The program has been tested against time studies of actual hauling operations carried out in 1981. In these tests, the empty and loaded one-way times predicted by the program were compared to those determined by the time studies. Of the 15 times tested, 8 were within 6% and 13 were within 12%. Further testing and adjustments will be done in 1982.

### Ultra Low Volume (ULV) Backpack Sprayer Modifications

The purpose of this project is to provide a safer use with higher productivity of ULV herbicide spray for brush control. These herbicide sprayer units were tested in the 1981 season and showed considerable promise. Minor modifications were made during the winter. The units are considered operational, but have been used only for test spraying to date.

### Mini-High Lead (ULV) Sprayer

At the request of Silviculture Branch, the design and fabrication of a mini-skyline ULV sprayer system is nearing completion.

The system is to be used on heavily brushed areas and is expected to be more efficient than alternative ULV applications. Field testing is scheduled for spring 1982. Using the mini-skyline system, the ULV sprayer can be used to apply a more consistent coverage of herbicides while keeping the operators away from the spray and sprayer.

## Herbicide Injector Lance

Engineering Branch, at the request of Silviculture Branch, is involved in the design of a lance-type herbicide applicator for stand treatment. This form of herbicide application is considered an improvement over traditional hack and squirt methods in that a measured amount of herbicide is applied to an individual tree and operator contact with the herbicide is minimized. Prototype lances received initial field testing in the 1981 season and operational trials are planned for the 1982 season.

## Skidder V-Blade Study

Blades mounted in front of wheeled skidders do not adequately clear debris when site preparation attachments are being towed. Silviculture Branch has requested Engineering Branch to look into the availability, design and fabrication of suitable blades.

A product search and preliminary field trials have resulted in a new V-Blade design. Fabrication incorporating several modifications to the original design is underway. Automatic height-adjustment assembly will be part of this improved V-Blade design.

# LICENSEE RESEARCH PROJECTS - SECTION 88(2)

## VANCOUVER FOREST REGION

### B.C. Forest Products Ltd.

#### AN ECOSYSTEM EVALUATION OF FORESTS ON THE WEST COAST OF VANCOUVER ISLAND WITH EMPHASIS ON THE CWHb BIOGEOCLIMATIC SUBZONE (#22-09-01)

The project is a co-operative study between the Ministry of Forests (Vancouver Forest Region) and British Columbia Forest Products Limited. Between 1978 and 1980, approximately 150 plots were established on the west coast of Vancouver Island. In each of these plots, environmental, soil, vegetative and tree mensuration data were collected with the intent of differentiating and characterizing distinct ecological units within the CWH Zone. Management interpretations for each of these units are to be based on data collected. During 1981, many of the physical and chemical soil analyses were completed. Most of the data were organized and coded for computer processing.

### Canadian Forest Products Ltd.

#### SOIL, TERRAIN AND BIOGEOCLIMATIC MAPPING OF THE TSITIKA WATERSHED (#37-001)

The objective of this project is to obtain detailed ecological and soil data for use in formulating silvicultural prescriptions, planning harvesting operations and road construction. A consulting firm has been contracted to survey that portion of the Tsitika watershed lying within TFL #37. Field work was completed in 1981 and final maps will be finished by early 1982.

#### DOUGLAS FIR PROVENANCE TRIAL (#59-1)

The objective of this study is to determine the effects of genetic and environmental factors on distinct provenances of Douglas fir. Canadian Forest Products Ltd. established plots with 2-year old stock in cooperation with CTIC. Twenty-five year remeasurements on the Eve River and Kaipit Creek provenance plots were completed in October 1981. Diameter and height measurements were taken on approximately 1 600 trees. The results were compiled and sent to Dr. K.K. Ching of Oregon State University for analysis. Results will be available in 1982.

## Crown Zellerbach Canada Ltd.

### SURVIVAL TEST - SPECIES SURVIVAL STUDY (#2-004)

The objective is to determine the biological effectiveness in terms of survival of container grown seedlings as compared to bare root stock. A final report was submitted with the conclusion that Styro-2 plugs were the most cost effective seedling alternative.

### COMPETITION OF UNDERSTORY TREES IN A JUVENILE SPACED STAND (#2-009)

The objective of the study is to assess the competition effect of uncut small trees on the crop trees after thinning. The study plots were established in 15-year old stands of Douglas fir (good, medium, and poor sites), western hemlock (good sites), and Sitka spruce (good sites) on Vancouver Island. The analysis of 4 year growth response indicated no adverse effects to leaving understory trees shorter than breast height (1.3 m), in fact crop trees had better height growth than in completely thinned stands.

### NITROGEN FERTILIZATION OF COASTAL WESTERN HEMLOCK (#2-014)

The objectives are to determine the growth response of nitrogen fertilized, spaced young stands of coastal western hemlock on TFL 2, and to evaluate operational cruise techniques for growth response estimates of fertilized timber types. An interim report of the 2 year growth response of western hemlock to juvenile spacing and operational aerial fertilization was submitted October 1981. The analysis indicates a positive growth response. Plot remeasurements are planned for 1982 and 1984. An additional interim report will be submitted in 1983 and a final report in 1985.

### ECOSYSTEM SURVEY OF TFL 2 BLOCK 17, BONANZA LAKE PHASE I (#2-016)

The objective is to develop a decision aid in map form for planning, harvesting and silvicultural procedures and to satisfy the land classification plan as approved in TFL 2 Working Plan No. 6. Phase I field mapping of soils, terrain and ecosystem units has been completed and a draft report format prepared. Phase II began December 1981 to prepare final maps, report and field guide.

## MacMillan Bloedel Limited

### WESTERN RED CEDAR CONTAINER PLANTING TRIAL (#312-4)

This project is a field test of Ray Leach, Spencer Lamaire, paper pot, Styro-4 and bare root stock types of western red cedar. Provenance effects were investigated using three provenances (Kennedy Lake, Sproat Lake and Port McNeill), and the field test sites were established as close to the original provenance locations as possible. Survival over the first 2 years of the test ranged from 75 to 99% with no significant stock type, provenance or location effects. Height growth has been erratic among the stock types during the first 2 years. At the end of the second growing season, bare root stock remained the tallest and had a growth rate comparable to the Ray Leach and Spencer Lamaire containers. However, all container types have consistently gained on bare root stock during the first 2 years. Paper pots remain the poorest growers over all provenances and locations tested.

## EFFECTS OF NITROGEN ON THE ACCRETION OF ABOVE GROUND BIOMASS (#552-1)

The objective of this project is to assess the effects of red alder and Sitka alder on the total ecosystem biomass accretion in a 22-year old Douglas fir plantation on Mt. Benson.

The presence of red alder increased total ecosystem biomass by 260% over the control site with no alder in a 22-year old Douglas fir plantation, while the Sitka alder present caused an increase of 74% in the same stand. The increase in total stemwood biomass was 217% for the red alder - Douglas fir area and 47% for the Sitka alder - Douglas fir area. Douglas fir stemwood biomass was not reduced by the presence of the Sitka alder component but was reduced by 28% in the plots with red alder.

## EFFECTS OF NITROGEN ON FOLIAR NUTRIENT CONCENTRATION: MT. BENSON (#552-2)

The objective of the study is to assess the changes in foliar nutrition of the Douglas fir due to the presence of either alder species. Douglas fir foliage from the alder sites contained higher concentrations of N than foliage from the no alder sites, but lower concentrations of P, S, Mn and Fe. The decreases in concentration were proportionally greater than the increases in N concentration.

## EFFECTS OF NITROGEN FIXATION ON BIOMASS PRODUCTION AND ACCRETION IN SITKA ALDER NEAR GREEN MOUNTAIN (#552-4)

The objective of the study is to assess the current rate of nitrogen fixation and biomass production in a young (5-year old) Sitka alder stand. Acetylene reduction assays yielded a nitrogen fixation estimate of 35 kg/ha/yr. The biomass of leaves, stems, roots and nodules was 13 700 kg/ha and above ground net primary production was 6 000 kg/ha/yr.

## FATE OF BIOLOGICALLY-FIXED NITROGEN (#552-7)

Literature evidence suggests that the N fixed by alder, cycles more actively than does the N already present, and/or that adding N increases the rate at which the N already present is utilized.

Assessing the natural abundance level of the stable $N^{15}$ isotope may provide a method for tracing alder-fixed N. The N fixation process kinetically discriminates against the heavier $N^{15}$ isotope in favour of the lighter $N^{14}$. As a result, biologically-fixed N is depleted in $N^{15}$ relative to atmospheric N. In addition, long-term soil processes tend to enrich total soil N in $N^{15}$, providing an even greater difference between fixed N and soil N. This "tagging" of biologically fixed N with a $N^{15}/N^{14}$ ratio which differs from nitrogen previously within an ecosystem, suggests the possibility of tracing the recently-fixed N and assessing its contribution to ecosystem N dynamics.

Using these methods, the estimated contribution of N fixation to the total N pool was 33%, approaching the direct estimates of 50%. This 1/3 increase in soil N from N fixation was accompanied by an approximately 2/3 contribution of alder-fixed N to available soil N; thus, alder-fixed N appeared about twice as 'active' as the available native soil N. Nitrification did not discriminate against $N^{15}$.

## EFFECTS OF ALDER ON SOIL NUTRIENT AVAILABILITY (#552-8)

Total soil N was found to be a better predictor of Douglas fir seedling N than all other nitrogen availability indices. One reason may be that the gradient in total soil N was a result of recent nitrogen fixation by alder, and this recent nitrogen could be more readily available than "older" soil nitrogen. Given the sources of variability in such blind correlations of available nitrogen indices, it would appear that total soil N is as good a predictor as any other index yet tested for forest soils. Therefore, refinement of predictions of responses to fertilization will probably result from an integration of soil chemical properties with on-site environmental conditions and regular nitrogen mineralization processes.

In the investigation of N, P and S limitations on Douglas fir growth, the Sitka alder soils produced the largest seedlings, followed by the red alder soil. The no alder soil produced the smallest seedlings. No significant seedling response to fertilizer was noted in the Sitka alder soil, whereas P consistently improved growth in the red alder soils. All three nutrient additions were required to achieve maximum growth in the no alder soil. Root/shoot ratios were more sensitive to nutrition than total growth of the seedlings; several root/shoot ratios shifted with fertilizer treatments which did not increase growth. The root/shoot patterns between the three sites without fertilization were consistent with the tree vigor indices measured in the field; Sitka alder soils gave the lowest root/shoot ratio and had the highest tree vigor index for the Douglas fir.

The seedling nutrient contents followed the expected patterns; the no alder soils provided the smallest quantities of all nutrients, and required a balanced supply of N, P and S before the seedlings could respond to any of the nutrient additions. The responses of the two alder site soils differed primarily in relation to a limitation of P in the red alder site soils.

This bioassay did demonstrate that the depressed P levels in Douglas fir foliage from the field were not just a result of competition with associated alder; soil availability appears to have decreased as a result of 22 years of Douglas fir/alder growth on the site. The accumulation of P in standing biomass and organic detritus appeared to account for the differences between the ecosystems; P accumulation in these pools for the no alder, Sitka alder and red alder ecosystems was 45, 105 and 150 kg/ha. Despite the low levels of total sulfur and sulfate in Douglas fir foliage from the field, no response to sulfur fertilization was observed under greenhouse conditions.

No biomass or nitrogen fixation response to added molybdenum (Mo) was found when assessing Mo and P+S limitations on red alder forests. The P+S treatment increased above ground biomass 2.6 fold and below ground 1.6 fold, reducing the root/shoot ratio from about 0.8 to 0.5. Nodule biomass increased 2.2 times as a result of P+S addition and nodule activity per gram increased 2.4 times, yielding a 5.3 fold increase in nitrogen fixation (acetylene reduction) activity per plant.

## IMPACT OF CEANOTHUS SANQUINEUS ON DOUGLAS FIR FOLIAR NUTRITION (#553-4)

Soil and foliage nutrient contents of Douglas fir saplings were determined in areas without redstem (Ceanothus sanguineus Pursh), at the edges of redstem patches, and within redstem patches. Total soil N (0-15 cm depth) was 50 to 75% greater at the edge of and within redstem patches than in areas without redstem. Assuming soil N was initially similar at all three positions, N accretion was 40 to 60 kg/ha/yr for 10 years. Available N index and extractable Ca and Mg were two to three times greater at the edges of and within the redstem patches than outside the patches. Concentrations of N, Ca and Mg in the Douglas fir foliage were lowest outside the patches, intermediate at the edges, and highest within the patches. Because needle weight was lower for saplings within patches than for those at the edges, the latter had the greatest foliar nutrient content. Redstem's enhancement of site fertility, as well as its potential benefits to wildlife and slope stability, make it an attractive candidate for mixed plantations with conifers.

## MANAGEMENT OF LEGUMES IN FORESTRY: EFFECTS OF NATURALLY OCCURRING LEGUMES ON CONIFER GROWTH AND NUTRITION (#555-5)

The study site is located in Chemainus Division and involves two areas; one is a portion of the plantation underlain by native lupines, the second is an area without lupines. Visually, the Douglas fir on the lupine site were more vigorous, had greener foliage and had fewer twisted leaders. Sampling has been completed to determine comparative soil and foliar N levels and tree growth. A final report will be completed by mid-1982, but site monitoring will be continued for at least the next 5 years.

## SECOND GROWTH DEER WINTER RANGE STUDY (#616-17)

This project was implemented in 1981 in an attempt to determine if older second growth in Shawnigan Division (60+ years) can function as alternate deer winter range under heavy snow conditions. The study method is to compare deer utilization of selected older second growth and old growth stands in winter using track frequencies in snow as an index statistic. The study is being carried out as part of the IWIFR program.

## Western Forest Products Ltd.

## EFFECTIVENESS OF DIFFERENT COMBINATIONS OF PLANTATION ESTABLISHMENT TECHNIQUES (#25-001)

The objectives are to compare combinations of fertilization, three levels of weed control and browse repellent and their stimulation of growth of 1+0 mudpack and 2+0 RP Douglas fir seedlings following planting.

The trial was established on high site land near Jordan River and has been measured once for survival and initial growth. The results have not yet been analysed.

## ECOSYSTEM MAPPING OF TFL 6 BLOCK 4 HOLBERG (#6-001)

A 5 year ecosystem classification and mapping program commenced in fall 1981. Field work was carried out over approximately 10 500 ha in Block 4. Classification and mapping procedures follow the Ministry of Forests approach using MOF slope transect and plot evaluation techniques and RAB-MOF standard data forms. Interpretation of field data and ecosystem unit deliniation has been started for this area.

## RE-ESTABLISHMENT TECHNIQUES FOR S1 ECOSYSTEM OF CWHe TFL 25 BLOCK 4 (#25-002)

This project is an evaluation of the effects of cultivation, slashburning and weed control on the establishment and growth of western hemlock, western red cedar and amabilis fir on the S1 (CH phase) ecosystem. The trial was planted in February 1982.

## EFFECTS OF SLASHBURNING ON NUTRIENT CONCENTRATIONS (#25-003)

This is a preliminary study to assess the impact of slashburning on soils along the upper San Juan ridge area at an elevation of approximately 800 m. Pre-burning and post-burning nutrient profiles are being compared. Data analysis is currently in progress.

## LICENSEE EXPERIMENTAL PROJECTS

| Sect 88 Number | Licensee Project Number | Project Title | Company |
|---|---|---|---|
| EV 2 | 312-4 | Western red cedar container planting trial | MB |
| EV 5 | 25-001 | Effectiveness of different combinations of plantation establishment techniques | WFP |
| EV 7 | 616-17 | Second growth deer winter range study | MB |
| EV 8 | 22-09-01 | An ecosystem evaluation of forests on the West Coast of Vancouver Island with emphasis on the CWHb Biogeoclimatic Subzone | BCFP |
| EV 13 | 555-5 | Management of legumes in forestry: effects of naturally occurring legumes on conifer growth and nutrition | MB |
| EV 14 | 552-2 | Effects of nitrogen on foliar nutrient concentration: Mt. Benson | MB |
| EV 15 | 552-1 | Effects of nitrogen on the accretion of above-ground biomass | MB |
| EV 17 | 552-4 | Effects of nitrogen fixation on biomass production | MB |

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|---|---|---|---|
| EV 18 | 552-7 | Fate of biologically-fixed nitrogen | MB |
| EV 19 | 552-8 | Effects of alder on soil nutrient availability | MB |
| EV 20 | 553-4 | Impact of Ceanothus sanguineus on Douglas fir foliar nutrition | MB |
| EV 25 | 552-9 | Interactions of alder and Douglas fir | MB |
| EV 30 | 37-001 | Soil, terrain and biogeoclimatic mapping of the Tsitika watershed | CFP |
| EV 31 | 2-011 | Economic analysis of nitrogen fertilization of Douglas fir | CZ |
| EV 32 | 2-009 | Competition of understory trees in a juvenile spaced stand | CZ |
| EV 33 | 2-004 | Survival test - species survival study | CZ |
| EV 34 | 2-014 | Nitrogen fertilization of coastal western hemlock | CZ |
| EV 36 | 6-001 | Ecosystem mapping of TFL 6 Blk. 4, Holberg | WFP |
| EV 37 | 2-016 | Ecosystem survey of TFL 2 Blk. 17, Bonanza Lake, Phase I | CZ |
| EV 39 | 59-1 | Douglas fir provenance trial | CFP |
| EV 40 | 2-016 | Ecosystem survey of TFL 2 Blk. 17, Bonanza Lake, Phase II | CZ |
| EV 41 | 25-002 | Re-establishment techniques for S1 Ecosystem on TFL 25, Blk 4 | WFP |
| EV 42 | 25-003 | Effects of slashburning on nutrient concentrations | WFP |
| EV 43 | 22-09-01 | An ecosystem evaluation second phase | BCFP |

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# PERSONNEL OF THE RESEARCH BRANCH AT MARCH 31, 1982

## R.L. SCHMIDT, DIRECTOR

## RESEARCH GROUP

### ECOLOGY and EARTH SCIENCES

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| M.D. Meagher, Ph.D. | Tree Breeder | Victoria |
| J.C. Heaman | Tree Breeder | Victoria |
| R.N. Hattie | Tree Breeding Technician | Victoria |
| C.C. Ying, Ph.D. | Tree Breeder | Victoria |
| D.J. St. Pierre | Provenance Technician | Victoria |
| R.L. White | Provenance Technician | Victoria |
| D.P. Ashbee | Provenance Technician | Victoria |
| S.A. Andersen | Senior Technician | Red Rock |
| W.R. Taylor | Propagation Technician | Red Rock |
| S.A.I. Karlsson | Manager, Research Station | Cowichan Lake |
| D.W. Carson | Superintendent, Nursery and Camp | Cowichan Lake |
| D.R. Patton | Buildings Maintenance Man | Cowichan Lake |
| I. Cairns | Nursery Technician | Cowichan lake |
| R.J. Dawson | Tree Breeding Technician | Cowichan lake |
| L.F. Pilcher | Labourer | Cowichan lake |

## SILVICULTURE

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| S.G.J. Homoky | Silviculturist Rehabilitation | Victoria |
| K.F. Bradley | Silviculturist Technician | Victoria |
| D. Draper, Ph.D. | Sivilculturist North | Red Rock |
| W. Johnstone, Ph.D. | Silviculturist South | Vernon |
| F.T. Pendl | Regional Research Officer | Vancouver |
| J. Pollack | Regional Research Officer | Prince Rupert |
| L. Snell | Research Assistant | Prince Rupert |
| L.J. Herring | Regional Research Officer | Prince George |
| H.G. Coates | Research Assistant | Prince George |
| M.B. Clark | Regional Research Officer | Kamloops |
| E.D. Elmes | Research Assistant | Kamloops |
| C.F. Thompson | Regional Research Officer | Nelson |
| P. Wray | Research Assistant | Nelson |
| A.H. Vyse | Regional Research Officer | Williams Lake |
| W. Mitchell | Research Assistant | Williams Lake |

## RESEARCH SUPPORT GROUP

### BIOMETRICS

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| M. Kovats | Manager Systems and Biometrics | Victoria |
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| H.B. Stauffer, Ph.D. | Technical Advisor, Biometrics Sampling | Victoria |
| Vacant | Technical Advisor, Experimental Design and Analysis | Victoria |

### ADMINISTRATION

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| G. Archibald | Manager Support Services | Victoria |
| P.W. Chester | Senior Clerk | Victoria |
| D.K. Garthwaite | Draughtsman | Victoria |
| L.A. Dobell | Secretary | Victoria |
| C.L.M. Ward | Word Processor Operator | Victoria |
| E.M. Lomas | Word Processor Operator | Victoria |
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## CONTRACT AND AUXILIARY RESEARCHERS

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| T. Ballard, Ph.D. | Silviculture |
| J. Bassman, Ph.D. | Silviculture |
| W. Biggs | Ecology |
| T.A. Black, Ph.D. | Ecology |
| R. Brockley | Silviculture |
| F. Bunnell, Ph.D. | Ecology |
| J. Bunning | Ecology |
| D. Bustard | Ecology |
| I. Cameron | Biometrics |
| W.W. Carr | Silviculture |
| T. Carson | Ecology |
| D. Coates | Silviculture |
| Y. Cohen, Ph.D. | Ecology |
| B. D'Anjou | Silviculture |
| A. Eastham | Physiology |
| B. Eccles | Ecology |
| R. Ellis | Ecology |
| Environmental and Social Systems Analysts | Ecology |
| R. Fahlman | Silviculture |
| M. Feller, Ph.D. | Ecology |
| Canada Department of Fisheries and Oceans | Ecology |
| V.E. Fletcher | Biometrics |

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| D.G. Giles | Ecology |
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| G.A. Godfrey, Ph.D. | Silviculture |
| J. Goudie | Silviculture |
| T. Goward | Ecology |
| R.N. Green | Ecology |
| E. Hamilton | Ecology |
| E.A. Harding | Ecology |
| A. Harestad, Ph.D. | Ecology |
| D. Hatler | Ecology |
| R.A. Hawes, Ph.D. | Ecology |
| B. Jaquish | Tree Improvement |
| M. Ketcheson | Ecology |
| C. Leadem, Ph.D. | Physiology |
| T. Lewis, Ph.D. | Ecology |
| D.A. Lloyd | Ecology |
| C.J. Marchant, Ph.D. | Silviculture |
| V. Marshall, Ph.D. | Silviculture |
| T.T. McIntosh | Ecology |
| S. McNaughton | Ecology |
| D.V. Meidinger | Ecology |
| T.D. Mock | Communications |
| A. Nicholson | Ecology |
| D.W. Ormerod | Biometrics |
| J. Otchere-Boateng, Ph.D. | Ecology |
| J.N. Owens, Ph.D. | Physiology |
| R.T. Pack | Ecology |
| M.D. Pitt, Ph.D. | Ecology |
| V.A. Poulin | Ecology |
| S.D. Ross, Ph.D. | Physiology |
| R.W. Rouse, Ph.D. | Ecology |
| K. Sadoway | Ecology |
| R.K. Scagel | Ecology |
| J.W. Schwab | Ecology |
| K. Scoullar | Ecology |
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| S. Stevenson | Ecology |
| L. Stordeur | Ecology |
| B. Storey | Ecology |
| T.P. Sullivan, Ph.D. | Silviculture |
| G. Tomlins, Ph.D. | Ecology |
| Transamerica Environmental Science Consultants | Silviculture |
| E.K. Watson | Ecology |
| B. Wikeem | Ecology |
| J.G. Worrall, Ph.D. | Silviculture |

## LIST OF TREES

| COMMON NAME | BOTANICAL NAME |
|---|---|
| Douglas fir | *Pseudotsuga menziesii* (Mirb.) Franco |
| subalpine fir | *Abies lasiocarpa* (Hook.) Nutt. |
| amabilis fir | *Abies amabilis* (Dougl.) Forbes |
| noble fir | *Abies procera* Rehd. |
| grand fir | *Abies grandis* (Dougl.) Lindl. |
| lodgepole pine | *Pinus contorta* Dougl. ex Loud. |
| western white pine | *Pinus monticola* Dougl. ex D. Donn |
| Ponderosa pine | *Pinus ponderosa* Dougl. ex Laws. and Laws. |
| Scots pine | *Pinus sylvestris* L. |
| red pine | *Pinus resinosa* Ait. |
| whitebark pine | *Pinus albicaulis* |
| Sitka spruce | *Picea sitchensis* (Bong.) Carr. |
| white spruce | *Picea glauca* (Moench) Voss |
| Engelmann spruce | *Picea engelmannii* Parry ex Engelm. |
| Norway spruce | *Picea abies* (L.) Karst. |
| western hemlock | *Tsuga heterophylla* (Raf.) Sarg. |
| mountain hemlock | *Tsuga mertensiana* (Bong.) Carr. |
| western red cedar | *Thuja plicata* Donn |
| yellow cedar | *Chamaecyparis nootkatensis* (D. Don) Spach |
| Port Orford cedar | *Chamaecyparis lawsoniana* (A. Murr.) Parl. |
| western larch | *Larix occidentalis* Nutt. |
| alpine larch | *Larix lyallii* |
| red alder | *Alnus rubra* Bong. |

## BIOGEOCLIMATIC UNITS CITED

BWBS - Boreal White and Black Spruce Zone

| | |
|---|---|
| BWBSa | Northeastern Boreal White and Black Spruce Subzone |

CWH - Coastal Western Hemlock Zone

| | |
|---|---|
| CWHb | Wetter Maritime Coastal Western Hemlock Subzone |
| CWHf | Northern Amabilis Fir Coastal Western Hemlock Subzone |
| CWHg | Queen Charlotte Islands Coastal Western Hemlock Subzone |
| CWHh | Mid-coast Drier Transitional Coastal Western Hemlock Subzone |
| CWHi | Mid-coast Wetter Maritime Coastal Western Hemlock Subzone |

ESSF - Engelmann Spruce - Subalpine Fir Zone

| | |
|---|---|
| ESSFa | Dry Southern Cordilleran Forested Engelmann Spruce - Subalpine Fir Subzone |

| | |
|---|---|
| ESSFb | Wet Interior Mountain Hemlock Forested Engelmann Spruce - Subalpine Fir Subzone |
| ESSFc | Moist Southern Forested Engelmann Spruce - Subalpine Fir Subzone |
| ESSFe2 | Okanagan Highlands Dry Southern Forested Engelmann Spruce - Subalpine Fir Variant |
| ESSFh | Wet Central Forested Engelmann Spruce - Subalpine Fir Subzone |

ICH - Interior Cedar - Hemlock Zone

| | |
|---|---|
| ICHa | Moist Southern Interior Cedar - Hemlock Subzone |
| ICHb | Wet Interior Cedar - Hemlock Subzone |
| ICHc | Moist-Cool Southern Interior Cedar - Hemlock Subzone |
| ICHf | Very Wet Northern Interior Cedar - Hemlock Subzone |
| ICHg | Northern Transitional Interior Cedar - Hemlock Subzone |
| ICHj | Moist Northern Interior Cedar - Hemlock Subzone |
| ICHk | Wet Northern Interior Cedar - Hemlock Subzone |

IDF - Interior Douglas Fir Zone

| | |
|---|---|
| IDFa | Very Dry Submontane Interior Douglas Fir Subzone |
| IDFb | Very Dry Montane Interior Douglas Fir Subzone |
| IDFf | Dry Southern Submontane Interior Douglas Fir Subzone |
| IDFg | Dry Cordilleran Interior Douglas Fir Subzone |

MH - Mountain Hemlock Zone

| | |
|---|---|
| MHa | Maritime Forested Mountain Hemlock Subzone |

MS - Montane Spruce Zone

| | |
|---|---|
| MSa | Dry Southern Cordilleran Montane Spruce Subzone |
| MSb2 | Okanagan Highlands Dry Montane Spruce Variant |
| MSc | Very Dry Southern Montane Spruce Subzone |

PPBG - Ponderosa Pine - Bunchgrass Zone

SBS - Sub-Boreal Spruce Zone

| | |
|---|---|
| SBSa | Chilcotin Pine Sub-Boreal Spruce Subzone |
| SBSb | Douglas Fir - White Spruce Sub-Boreal Spruce Subzone |
| SBSc | White Spruce - Subalpine Fir - Douglas Fir Sub-Boreal Spruce Subzone |
| SBSe | Subalpine Fir Sub-Boreal Spruce Subzone |
| SBSf | Wet Sub-Boreal Spruce Subzone |
| SBSh | Dry Eastern Cordilleran Sub-Boreal Spruce Subzone |

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